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VOLUME CII

## SCIENTIFIC REPORT
## OF THE BALTIC AND TRANSITION AREA COMMITTEES
## FOREIGN GUESTS IN THE BALTIC AND TRANSITION AREAS

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# PREFACE

IN the combined Meeting of the Baltic and Transition Area Committees, on June the 6th 1934, several instances of apparently unusual occurrence of foreign guests in the waters of the Baltic and the Transition Areas were cited. During the following discussion of these phenomena it was pointed out by several members of the Committees that it would be most desirable to collect all data available on this subject with a general review of the hydrographical conditions of the waters in question during later years. Further it was unanimously agreed to recommend to the Consultative Committee to publish a paper on this matter with contributions from different countries bordering these waters. Having carried this proposition to the Editorial Committee and to the Council it was accepted by the International Council at its meeting on June the 1st 1935 and the chairmen of the two Committees were appointed co-editors of the publication which is hereby presented.

From the papers it will appear that the waters of the areas in question periodically have shown higher salinities and temperatures than ordinarily considered normal; no doubt the increasing salinity has been caused essentially by unusual strong inflow of water. In connexion with this inflow it is further shown that several species of invertebrates as well as fish have penetrated further south towards the Baltic — and into the Baltic even — than usual, and species normally considered rare visitors have been recorded in greater numbers; species of food-fish have occurred in such quantities even that they have been subject to commercial fishing.

The change in hydrographic and faunistic conditions, however, is apparently of temporary character only.

We are indebted to the authors: K. Altnöder, Aage J. C. Jensen, Cl. Künne, P. F. Meyer and Erik M. Poulsen for kindly contributing to this publication. After a general review of hydrographic conditions we are giving the papers in the order in which they are received and apologize to authors who have given their contributions long ago for the unavoidable delay due to the last contributions, but recently received; an Appendix is attached to this paper on "The composition of the Polish sprat catches in the Bay of Danzig in the seasons 1934—35 and 1935—36" by Boris Dixon.

H. Blegvad. K. Andersson.

# I.

# FLUCTUATIONS IN THE HYDROGRAPHY OF THE TRANSITION AREA DURING 50 YEARS.

BY

AAGE J. C. JENSEN.

(MS. received January 1937)

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## I. Purpose of the Investigation.

appears from numerous investigations that the fluctuations in the composition and abundance of the stocks of fish are due to fluctuating ical conditions. An investigation of this kind special interest in a boundary area like the sition Area: here the fluctuations are parti- rly pronounced thus allowing an easier and r estimate of facts.

The qualities of the water (salinity, temperature, ents, etc.) vary from day to day. Such changes more or less, dependent on a periodical annual ation which, on the other hand, is caused by the al periodical variation of the climatic factors. e look at conditions at corresponding seasons, he mean condition of the year, we find very t changes from year to year, and in many s gradual alterations are found to take place he process of time. The periodicity of such ations may cover a series of several years, or may seem to be non-periodical. The following s contain a closer examination within the sition Area of the variations of current, ity, temperature and, partly, of the oxygen ent.

For purpose of orientation a very brief survey the hydrographical conditions generally pre- ng within the area is given in Section III. ion IV discusses the relationship between the ations of these hydrographical factors in the erent localities, special regard being paid to possibility of using such variations as an ression of fluctuations of currents and mixing esses.

In Section V the variations that have taken e in the course of years (perennial or "secular" ations) are examined.

## The Material of the Investigation and its Treatment.

The greater part of the hydrographical material l is: monthly, quarterly, and annual, means of daily observations of salinity and temperature various depths carried out from Danish light- s, and published in: *Nautisk-Meteorologisk bog (Nautical-meteorological annual).* — *Publikationer fra det danske meteorologiske Institut, København.* The other material used originates from Danish, Swedish, German, and Finnish publications, which are cited in their due places. The water-level observations from the Danish stations exist in manuscript only, but were most kindly placed at my disposal by Mr. D. la Cour, Director of the Danish Meteorological Institute, and Mr. J. Egedal, Government Meteorologist, to both of whom I beg to render my best thanks.

The figures considered are mostly monthly, quarterly and annual means.

To establish the connexion between the hydrographical factors of the different localities, and successive periods, correlation calculations were used extensively, this method apparently constituting the best basis of expressing the degree of co-variation by means of an average figure.

Whenever such procedure was practicable the different combinations possible were tested systematically.

It should be remembered of course that a calculation of correlation only gives the measure of the co-variation the precision of which is measured by the probability-limit of the standard error. The advantage of a correlation-calculation is a double one: we get a single figure for the degree of co-variation, and moreover it allows us to judge the reliability of the result.

When nothing else has been stated the calculations of correlation are based on the years 1898—1934 (37 years).

Calculated on the basis of 15, 29 and 37 pairs of observations the Probability (Level of significance) is (R. A. Fisher: Statistical Methods for Research Workers. Edinburgh & London. 1930. Table V A) for a total correlation:

| | | | |
|---|---|---|---|
| Probability ($P$) = | 0·05 | 0·02 | 0·01 |
| recorded from | | | |
| 15 pairs — $r$ = | 0·514 | 0·592 | 0·641 |
| 29 „ — $r$ = | 0·368 | 0·431 | 0·472 |
| 37 „ — $r$ = | 0·325 | 0·381 | 0·418 |

The correlation calculation may be used partly for purpose of *testing* connexions otherwise made probable, partly of establishing such connexions. Neither of these methods, however, gives an absolute answer, but an answer only within the

Fig. 1.

probability-limit of the standard error. The probability of the former method is a little greater than that obtained by calculation because the anticipative knowledge, too, bears out the result, but it should be kept in mind that also anticipative knowledge is subject to a probable error which, however, in most cases cannot be measured.

Any correlation carried out is one among an infinity of possibilities, and the probability of its showing the true value of the co-variation is the same whether these other calculations be carried out or not.

I am much obliged to Dr. J. P. Jacobse and Mr. Helge Thomsen for advice an colloquies during work on certain sections co cerning variations of the hydrographical condition I further wish to express my thanks to D H. Blegvad, Director of the Danish Biologic Station, for placing valuable assistance at m disposal during the investigation, and to Messr E. Kaas, J. Krause, L. P. Larsen, T Færregaard, M. Rudkjøbing and Mis I. Schultz for doing part of the calculation

The investigations on the water transport an

lependency on meteorological conditions has carried out by the author with the financial tance of the *Carlsbergfond*, to whom I beg nder my sincerest thanks.

## Brief Survey of the Hydrographical Conditions of the Transition Area.

### Water layers.

The water of the Kattegat, the Belt Sea, and Sound is generally found to be divided into al layers.

. The upper layer down to 5—20 m. depth, e eastern Kattegat often down to 30 m., shows mparatively low salinity due to outflowing r from the Baltic. The current changes ently, mostly under influence of wind, to less ee of tide; although mainly outgoing also an ing current is often recorded. A study of the hly means of current in one locality, as e. g. Schultz Grund L. V. where observations of nt were carried out at all depths every 4 hours ghout the years 1910—16, will show that the ting current of the upper water layer 12·5 m.) in the different quarters of the year ingoing in 39, 38, 38, and 14 % of the months ctively[1]); in the following this water layer is d the *upper layer* and the current the *upper nt.* A current directed from the Baltic towards North Sea is termed outgoing (and reckoned ive), the opposite one ingoing current.

. Below this upper layer we find a more erous water layer the resulting movement of h goes from the North Sea through the erak towards the Baltic. The monthly mean is current is nearly always ingoing, sometimes an outgoing movement being extremely rare. he Schultz Grund L.-V. the monthly resulting nt of this water layer (12·5—26 m. depth) 0 in one month of the 7-year period, the other months showing an ingoing current. In the wing this water layer is called the *lower layer* the current the *lower current*, the ingoing nt is reckoned negative.

. Between the upper and lower layer there is i s c o n t i n u i t y l a y e r, which in summer uently shows a thickness of no more than —1·5 m. and which, as demonstrated by t t i n g, often moves independently of the hbouring layers.

. At depths of more than 40—50 m. in the egat from time to time we find a body of r originating from an intermediary water layer he Skagerak. The extent of this body is ibly of great importance to the fauna of the Kattegat, but observations are too few to follow its variations continuously throughout longer periods.

**5.** In the deep channels of the Belts strong currents often reach the bottom, but here we sometimes find a rather low oxygen saturation (as low as about 50 % in November); this is due to the oxygen consumption in the ingoing water which is moving comparatively slow and which has not, for an average of about 6 or 8 weeks, been in contact with the atmosphere[2]).

**6.** In the deeper parts of the western Baltic and the southernmost part of the Lille Belt, both bounded by barriers with shallower water, stagnant water of a pronounced sub-saturation of oxygen, sometimes with no oxygen at all, is often to be found during the summer, the autumn, and the early winter.

In the Baltic proper the depth of the upper layer increases eastwards, reaching about 30—40 m. round the Kriegers Flak and about 60 m. at Bornholm. The lower layer is recruited principally through a discontinuous inflow across the barriers at Drogden and at Gedser — Darss where the depths are 7—8 m. and about 10 m. respectively. The oxygen content is often very low on account of the oxygen consumption in the stagnant water. The average temperature of the bottom water in the Bornholm Basin in about 4·5°, which shows that the water is renewed principally during the winter season.

### B. Annual variations of salinity and temperature and their causes.

**1.** A n n u a l v a r i a t i o n.

Figures 2 and 3 show the annual variation of the monthly mean salinity at surface and bottom[3]). The salinity of both upper and lower layer generally increases with depth on account of an intermixing of the two bodies of water through the discontinuity layer, while intense vertical mixings within each layer continuously works at making the water of this layer homogeneous.

The annual variation of the temperature of the surface water follows that of the atmosphere although with a small difference of about one or two weeks due to the higher specific heat of the water.

In the lower parts of the upper layer the phase difference is slightly greater, principally on account of the intermixing with the lower layer. In the latter there is a phase difference of about 15 days

J. P. J a c o b s e n: Die Wasserumsetzung durch den nd, den grossen und den kleinen Belt. — Medd. f. n. f. Havundersøgelser. Ser. Hydrografi. Bd. II. Nr. 9. p. 46.

[2]) J. P. J a c o b s e n: Der Sauerstoffgehalt des Meereswassers in den dänischen Gewässern innerhalb Skagen. — Medd. f. Komm. f. Havundersøgelser. Ser. Hydrografi. Bd. I. Nr. 12. 1908.

[3]) Mean Values of Observations from Danish Light-Vessels. — Publikationer fra det Danske Meteorologiske Institut. København. 1933.

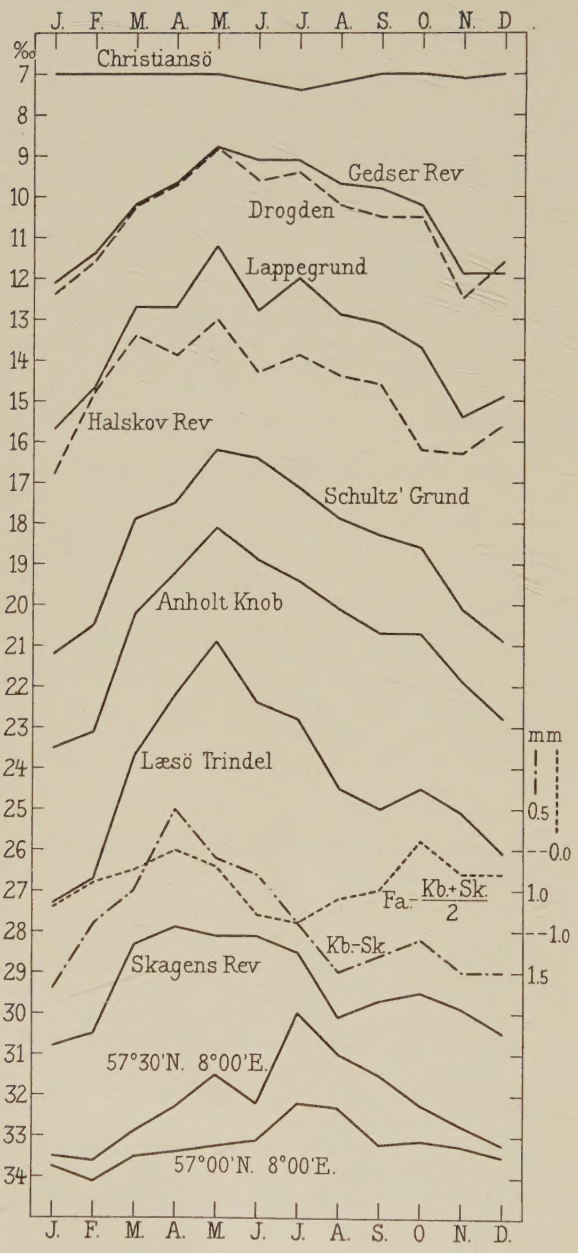


Fig. 2. Annual variation of salinity at the surface.

Western entrance to the Skagerak from: Atlas de température et salinité moyenne de l'eau de surface de la mer du nord et de la manche; publié par le Bureau du Conseil, Service Hydrographique, Copenhague 1933. The other salinity curves from: Mean values of observations from Danish light-vessels. Publikationer fra Det danske meteorologiske Institut. København 1933. Kb.—Sk. and Fa. $= \frac{\text{Kb.} + \text{Sk.}}{2}$: Differences of barometric pressure Copenhagen—Skagen, respectively, from: De danske meteorologiske Institut: Danmarks Klima. København 1933.

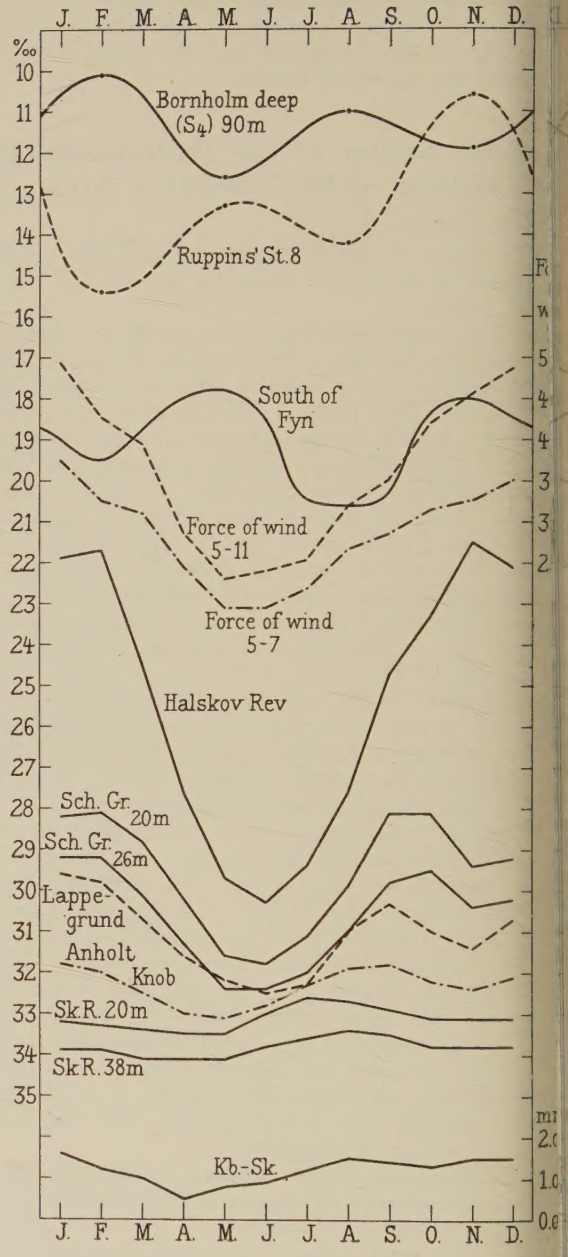


Fig. 3. Annual variation of salinity at the bottom.

Bornholm deep and Ruppin's St. 8 from: Ruppin, 191 South of Fyn from: Jacobsen, 1908. The other curve see Fig. 2.

ne Belts and about 6 months in the Baltic er.

s to the annual variation see further '. Jacobsen: 'Mittelwerte ..', Medd. f. m. f. Havunders. Ser. Hydrografi. Bd. I. Nr. 10. , Ruppin: 'Beitrag ..', Wissenschaftliche resuntersuchungen herausg. v. d. Kommission N. F. Bd. 14. Abt. Kiel. Nr. 10. 1912 and ehrke: 'Beiträge ..', Publications de Circon- e. 52. 1910.

auses of the annual variations f salinity.

he causes of the varying salinities throughout year have been discussed especially by Knudsen in 'De danske Farvandes Hydro- ', 1901, and in the above mentioned papers acobsen, Gehrke, E. Ruppin. The al period of salinity in the upper layer is ly influenced partly by the annual period of ertical convection, partly by the outflow of r from the Baltic.

*pper and lower layer in the Kattegat and the elt Sea, and upper layer in the Baltic proper.*

rom Figures 2 and 3 it will be seen that rally the annual variation of salinity in the r layer is contrary to that of the lower layer: ring and summer we find a minimum salinity ne upper layer, the lower layer at the same showing a maximum; in autumn things are sed.

he causes of this annual variation we know the above mentioned papers. The variation is 1°, to the annual variation of the vertical con- on; principally depending on the force of , the annual data of which are plotted in Figs. d 3; 2°, to the fact that the outflow from the c is at its highest in spring after the melting of ice and snow in the Baltic and surrounding areas. A direct effect of the increasing outflow is a drop in salinity in the upper layer in spring and, consequently, a decreasing convection between the upper and lower layer, and finally the outflow causes a reactive inflow of salt water through an alteration of the dynamic field.

Observations on the annual variations of current were made by Jacobsen[4]) (by direct observations of current and by calculations of the solenoid field); by Witting[5]) (by observations of water level and precipitation) and by Jacobsen[6]) (by direct observations of current).

All these observations tell of a more or less distinct primary maximum of outflow at surface during the spring months and a secondary maximum about September, i. e., when the salinity reaches a minimum.

Jacobsen's observations of current in the lower layer at the Schultz Grund show a maximum of ingoing current in winter simultaneously with the primary minimum of salinity. From this we may conclude that the annual changes of the force of inflow are of inferior importance to the annual variation in the salinity of the bottom layer in the southern Kattegat and the Belt Sea (cp. Table 1).

The annual variation of salinity in the upper and lower layer is also influenced by the annual variation of temperature. The fact that in winter

[4]) J. P. Jacobsen: Beitrag zur Hydrographie der dänischen Gewässer. — Medd. f. Komm. f. Havunders. Ser. Hydrografi. Bd. II. Nr. 2. 1913.

[5]) Rolf Witting: Hafsytan, Geoidytan och Landhöjningen utmed Baltiska Hafvet och vid Nordsjön. — Fennia. Bd. 39. No. 5. Helsingfors 1918.

[6]) J. P. Jacobsen: Die Wasserumsetzung durch den Øresund, den grossen und den kleinen Belt. Medd. f. Komm. f. Havunders. Ser. Hydrografi. Bd. II. No. 9. 1925.

## Table 1.

rage of currents (cm./sec.) at Schultz Grund L.V. at 25 m. Depth and in lower layer, resulting amount vater (km.³) passing through the section Refsnæs—Gyllingnæs (Jacobsen, 1925), mean salinity )—16, and air-pressure difference (mm.) Copenhagen—Skaw, Fanö—Copenhagen and Fanö—Skaw.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| rage current 25 m. ..... | —18 | —19 | —18 | —15 | —12 | —12 | —9 | —10 | —10 | —16 | —22 | —18 |
| rage current wer layer ..... | —18 | —22 | —20 | —17 | —14 | —15 | —11 | —13 | —13 | —18 | —26 | —22 |
| lting amount water ..... | 58·8 | 36·0 | 41·0 | 48·5 | 65·5 | 50·2 | 50·6 | 52·0 | 55·2 | 39·6 | —25·1 | 20·0 |
| n salinity ‰ .. | 29·1 | 29·3 | 30·3 | 30·9 | 31·9 | 32·1 | 32·2 | 31·6 | 31·1 | 29·8 | 31·1 | 30·8 |
| ltz Grund, Bottom rom.-press. diff. | | | | | | | | | | | | |
| —Co., c. 260 km. . | —1 | —2 | —2 | —2 | —2 | 3 | 3 | 0 | —2 | —7 | —5 | —5 |
| —Sk., c. 270 km. . | 16 | 12 | 10 | 5 | 8 | 9 | 12 | 15 | 14 | 13 | 15 | 15 |
| —Sk., c. 290 km. . | 15 | 10 | 8 | 5 | 6 | 12 | 15 | 15 | 12 | 6 | 10 | 10 |

the temperature is even from surface to bottom, or lower in the upper layer, favours the vertical convection, but in summer the latter is counteracted by the higher temperature of the upper layer.

Finally, the annual variation of salinity must be influenced to a slight degree by the annual variation in the salinity of the ingoing water of the lower layer. In the central and eastern part of the North Sea the salinity maximum occurs about February 1st, in the bottom water at the Skaw in April or May, and in the southern Kattegat the summer maximum, due to the insignificant vertical convection of this season, is intensified in early summer by this salinity maximum of the ingoing water, so that the maximum of the bottom salinity at the Schultz Grund in most cases will be recorded at the beginning of June.

On account of the comparatively rapid current in the surface layer the spring minimum of salinity occurs practically simultaneously throughout the Kattegat, the Belt Sea, and the Sound, and generally culminates in May.

The minimum in the upper layer is followed by an inflow of comparatively saline water in the lower layer, and this inflow brings about a salinity maximum of the bottom water at the Skaw in May, at lightvessels south of this place somewhat later corresponding to the water of the lower layer taking a certain time to spread southwards. As shown in IV, A, 3, a there is hardly any doubt that the inflow is caused by the outflow. At the Schultz Grund (26 m.) and Lappegrunden (23 m.) the maximum salinity is reached in June.

Thus we see that the outflow from the Baltic and the annual variation of the force of wind are of essential importance to the understanding of the annual salinity variation, but also the annual variation of the wind direction plays a considerable part.

The irregularities in the run of the annual curves of salinity between June and December (noticeable in Figures 2 and 3), which cannot be explained from the yearly range of outflow and force of wind, must no doubt be put down to the influence of the wind direction: it will be seen from the western wind component, which may be expressed approximately*) by the pressure gradient Copenhagen — Skaw (as plotted on Fig. 2 and shown in table 1), that this component reaches its maxima by January and August. In the same figure and table the northern component is expressed by the pressure gradient Fanø — Copenhagen. This component shows a maximum by June or July.

In September—October the values of the western wind component are a little lower than in August, and a considerable southern component of wind appears. Southerly or south-easte winds are comparatively frequent, and the salin of the upper layer now decreases, more particula in the northern Kattegat. This may be explain by the resulting south-westerly winds at the sa time extending the surface isohalines in the Bal in an eastern direction thus causing a lesser outflow from the Baltic and, consequently, th the tendency to an autumn minimum in salin is very weak in the Belt Sea.

The above mentioned secondary surface ma mum and minimum in the salinity of the northe Kattegat will induce an inflow of water compa tively poor or rich on salt, respectively, appeari in the curves of the year as a secondary minimu or maximum, spreading southward through t Kattegat, the Belt Sea and the Sound. At t Anholt Knob, Bottom, the minimum is record in August—September, at the Schultz Grun Bottom, in September—October (see Figure 3 the secondary maximum of these two localiti occurring in November and November—Decemb respectively. These maxima and minima of t lower layer are but slightly perceptible in t northern Kattegat where on the whole the annua variation of salinity in the lower layer is i considerable.

b. *The lower layer of the Baltic proper.*

The annual salinity variation in the lowe layer of the Baltic is absolutely different fro that found in the Kattegat and the Belts. We fin here a primary maximum, spreading eastward and in the western part between Scania and Rüge (cp. R u p p i n's St. 8 in Figure 3), occurrin about February 1st, because at this time ingoin waves of saliferous water across the barriers a Drogden and Gedser—Darss are particularly frequent. The force of wind is particularly grea in winter, and the Baltic current, at this tim flowing slowly is no great hindrance against th inflow; moreover, the slight difference in specific gravity between the upper and lower layer make it easy for water from the lower layer to be carried across the barriers. The maximum spreads towards Bornholm, reaching the Bornholm Basin about May 1st.

But also the higher summer maximum of salinity in the bottom layers of the Kattegat and the Belt Sea spreads into the Baltic proper, although as a secondary maximum only. Between Scania and Rügen it occurs about August 1st, in the Bornholm Basin about November 1st (the dates are approximate only, being based on quarterly research voyages).

c. *The total amount of salt.*

The measuring of the annual variation of the total amount of salt is a difficult problem. M. K n u d s e n has called attention to the southern

*) The force of the wind corresponding to a pressure difference varies considerably according to season.

**Table 2.**

rence in salinity (‰) between the Skagens Rev and the Schultz Grund (1903—26) and the Halskov Rev (1922—31), respectively.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 m.-Sch.G., 26 m. | 1·6 | 1·3 | —1·8 | —3·4 | —4·3 | —4·3 | —3·5 | —0·9 | —0·1 | 0·0 | 0·5 | 0·3 |
| 5 m.-Sch.G., 26 m. | 2·3 | 2·4 | 0·5 | —0·8 | —1·3 | —1·6 | —1·4 | 0·3 | 1·2 | 1·2 | 0·4 | 1·4 |
| 20 m.-Sch.G., 26 m. | 4·0 | 4·1 | 3·3 | 2·2 | 1·1 | 0·6 | 0·6 | 1·7 | 3·1 | 3·6 | 2·7 | 2·9 |
| 0 m.-Ha.R., 20 m. | 8·9 | 8·8 | 3·8 | 0·3 | 0·4 | —1·8 | —1·9 | 2·5 | 5·0 | 6·2 | 8·4 | 8·4 |
| 5 m.-Ha.R., 20 m. | 9·6 | 9·9 | 6·1 | 2·9 | 1·4 | 0·5 | 1·2 | 3·9 | 6·3 | 7·4 | 9·3 | 9·5 |

of the Lille Belt as the best field of vation, at which place the salinity is fairly rm from surface to bottom[7]). Here the ty reaches a minimum, 13 ‰, at bottom in and rises smoothly to the maximum, 17 ‰, bruary.

similar annual variation, with a minimum of 9 ‰ in May and a maximum of some 0 in January is recorded at Drogden, this ty too showing a fairly even salinity from e to bottom. However, no smooth rise of ty from minimum to maximum is found here, aratively low values occurring throughout the ner till about October. The minimum is caused e vigorous outflow in spring of water of aratively poor salinity from the Baltic, and naximum occurring when the greatest amount sh water is ice bound.

calculation of the mean salinities of the bodies from surface to bottom at the Schultz d and Anholt Knob Light Vessels will show ow values occur between March and November, values in December, January and February At the Schultz Grund the values seem to articularly low in September and October. uch low autumn values, which were also to prevail at Drogden, may be accounted by southerly and south-easterly winds being is season fairly prominent and causing a ase of the surface salinity, while at the same an inflow of water of comparatively poor ty takes place through the lower layer of the gat, induced by the somewhat higher salinity e upper layer during the previous months.

nnual change in difference of a inity between the Skagerak nd the Belts.

appears from the charts of mean salinity shed by Jacobsen[8]) and from figures 2 and 3 that the decrease of salinity, from the Skagerak to the Baltic, varies with seasons and areas. At the Skaw the monthly mean salinity varies by 1 ‰ at bottom and by 3 ‰ at surface.

It is seen from Table 2 that in the Kattegat and the Belt Sea the spring and summer seasons afford good conditions of an undisturbed faunistic connexion towards south, the difference of salinity being but small during this period. In June and July a fish will find a higher salinity in the lower layer of the Great Belt than at the surface at the Skaw. It further appears from the table that a secondary minimum in the difference of salinity is found throughout the Kattegat in November and December. Between March and August (inclusive) and in November—December the monthly mean salinity at the Schultz Grund, Bottom, is above 30 ‰.

## IV. Moving and Mixing of the Water Bodies.

### A. Moving of anomalies of salinity and temperature in the Kattegat and the Belts.

#### 1. The ingoing water movement in the lower layer.

a. *Phase differences between the occurrence of anomalies at the Skaw and at the Schultz Grund.*

A correlation for the years 1898—1934 of the monthly means of salinity and temperature at the Skagens Rev, Bottom, with the monthly means of salinity and temperature at the Schultz Grund, Bottom, in the same and the following months gives the values put down in Tables 3 and 4. It is seen that the variations of salinity may be followed from the Skaw to the Schultz Grund and that the period passing until an anomaly, observed at the Skaw in a certain month, shows the greatest positive correlation with the anomaly of salinity at the Schultz Grund is:

| | |
|---|---|
| from June to September: | 1 month; |
| from September to December: | 2 months; |
| from January to February: | 2—3 months; and |
| from March to May: | 2 months. |

Martin Knudsen: Der baltische Strom und alzgehalt im Kattegat und im westlischen Teile der . — Annalen der Hydrographie und Maritimen rologie. 1901.

J. P. Jacobsen: Mittelwerte von Temperatur und halt. — Medd. f. Komm. f. Havunders. Ser. Hydro- Bd. I. Nr. 10. 1908.

## Table 3.

Monthly means of salinity at Skagens Rev, Bottom, correlated with mean of salinity at Schultz Gru Bottom, in the same and the following months, respectively.

| Salinity, Sch. Gr., Bottom, in | Salinity, Skagens Rev, Bottom, in | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | De |
| same month ..... | —0·07 | —0·30 | —0·14 | —0·22 | —0·15 | —0·21 | —0·02 | 0·13 | —0·04 | —0·02 | —0·44 | —0· |
| 1 month later ..... | —0·02 | 0·15 | **0·45** | **0·40** | **0·36** | **0·24** | **0·53** | **0·62** | **0·38** | **0·24** | **0·18** | 0· |
| 2 months later ..... | **0·07** | **0·46** | **0·40** | 0·31 | 0·11 | —0·12 | 0·39 | —0·21 | 0·18 | 0·09 | 0·09 | **0·** |
| 3 months later ..... | —0·04 | **0·46** | 0·16 | —0·30 | —0·16 | —0·16 | —0·13 | —0·25 | 0·08 | 0·05 | —0·25 | —0· |
| 4 months later ..... | —0·01 | 0·13 | 0·20 | | | | | | | | | |

## Table 4.

Monthly means of temperature at Skagens Rev, Bottom, correlated with means of temperature at Schu Grund, Bottom, in the same and the following months, respectively.

| Temperature Sch. Gr., Bottom, in | Temperature, Skagens Rev, Bottom, in | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | De |
| same month ..... | 0·25 | 0·12 | —0·02 | 0·04 | 0·08 | 0·10 | 0·16 | 0·13 | 0·09 | 0·13 | 0·24 | 0· |
| 1 month later ..... | 0·36 | 0·29 | 0·35 | 0·10 | **0·37** | **0·38** | **0·30** | **0·57** | **0·51** | 0·28 | 0·37 | 0· |
| 2 months later ..... | **0·71** | **0·75** | **0·68** | **0·39** | **0·35** | —0·08 | 0·10 | **0·50** | 0·10 | **0·35** | 0·32 | **0·** |
| 3 months later ..... | 0·49 | **0·84** | **0·61** | **0·37** | 0·24 | —0·13 | 0·23 | 0·16 | 0·22 | **0·34** | **0·55** | 0· |
| 4 months later ..... | —0·04 | **0·70** | 0·27 | 0·27 | 0·15 | 0·13 | 0·01 | 0·30 | 0·16 | 0·30 | 0·27 | 0· |
| 5 months later ..... | 0·07 | 0·20 | | | | | | | | | | |

A correlation of the mean salinity at the Skaw Reef, Bottom, in the winter and summer quarters (1st and 3rd quarter) with the mean salinity at the Schultz Grund, Bottom, partly in the same quarter, partly in quarters differing 1, 2 and 3 months, gives the following coefficients.

## Table 5.

Salinity at the Skagens Rev, Bottom, in a certain quarter correlated with salinity at the Schultz Grund, Bottom, in the same quarter and in quarters displaced 1, 2, and 3 months respectively.

| | Salinity at Skagens Rev | |
|---|---|---|
| | 1st quarter | 3rd quarter |
| Salinity at Schultz Grund | | |
| same quarter ..... | 0·10 | 0·01 |
| quarter, 1 month later ..... | 0·06 | **0·42** |
| „ 2 months „ ..... | **0·35** | **0·30** |
| „ 3 „ „ ..... | **0·40** | 0·03 |

Coefficients that may be considered significant are also found here by differences of 2—3 months in winter and spring and of 1—2 months in summer and autumn.

b. *What conclusions may be drawn from the phase difference between the occurrence of an anomaly at the Skagens Rev and at the Schultz Grund?*

We know that a particularly strong inflow can be followed in most cases from one light vessel to another throughout the Kattegat by means of a high positive salt anomaly, as shown by M. Knudsen: (Havets Naturlære. — Skrifter udg. af Komm. f. Havunders. 1905. p. 38) and A. C. Johansen[9]) in the case of the vigorou inflow of the spring of 1923.

If, however, we examine the salinity of th lower layer at a certain locality in the Kattega e.g., at the Schultz Grund, Bottom, we find tha it is at any time determined by 4 factors:

(1) mixing with the upper layer;
(2) strength of current;
(3) deep sea waves; and
(4) salinity of the incoming water body.

(1) The vertical convection might very wel cause a phase difference in salinity between th two localities, viz., if an anomaly of salinity o temperature was spreading downwards from th surface and required a shorter time to reach th bottom at the Skaw, where there is a smal difference in specific gravity between bottom an surface, than at the Schultz Grund where th difference is much greater.

However, a calculation of the correlatio between the salinities at surface and bottom show that such downward spreading of the anomalie exercises no perceptible influence on the monthly mean salinity at bottom. On the contrary: a high salinity at the surface will be followed by a low one at the bottom and *vice versa*. This is a natural consequence of the fact that a certain anomaly at surface alters the dynamic field, thus causing an inflow, which during the following period induces the reverse anomaly at bottom (see IV. A, 3, a).

[9]) A. C. Johansen: On the Influence of the currents upon the Frequency of the Mackerel in the Kattegat and adjacent parts of the Skagerak. — Medd. f. Komm. f. Havunders. Ser. Fiskeri. Bd. VIII. Nr. 8. 1923.

(2) The strength of the ingoing current and the nity of the water body transported may of rse to some degree vary independently although increasing strength of current will generally se a southbound extension, and a decreasing ngth a north bending extension of the alines. One might think that variations in the ngth of current would occur simultaneously in northern and southern Kattegat, but this is not case: a simultaneous increase of the ingoing rent at the Skaw and the Schultz Grund would se a simultaneous increase of salinity in the localities whereas a slackening or outgoing rent would decrease it. But the correlation ulation has established the tendency of a ative correlation between the salinity of the localities within the same month (cp. Table 13). As to places situated closer to each other like Skaw and the Anholt Knob or the Anholt ob and the Schultz Grund there is no doubt that nges in the strength of current in the lower r will in many cases run together, so that the alines of the two localities will be simultaneously extended in the same direction. This is one the causes of these localities showing a positive relation between the salinities of the same nth.

(3) The existence of deep sea waves was blished by Otto Pettersson (see e.g. er die Wahrscheinlichkeit von periodischen und eriodischen Schwankungen in dem atlantischen me und ihren Beziehungen zu meteorologischen biologischen Phaenomenen', Sv. hydr.-biol. nm. Skr. II. 1905). They move through the tegat, from north to south, in the course of about days, time changing somewhat according to the mentary conditions of current. They cause a itive correlation between the salinity at the w in one month and at the Schultz Grund ecially within the same month, to some degree, wever, also in the following ones. But it appears m the table that for the same month a negative relation exists between the means of the month, correlation showing rather high values in ter, spring and early summer: throughout this iod these waves will not affect the monthly ans of salinity. They possibly play an inferior t between July and October.

(4) Water of a certain salt anomaly entering Kattegat from the north will spread, *ceteris ibus*, through this water and the Belt Sea at ate of motion differing slightly from the average ed of the lower current, because the anomaly rs the solenoid field.

A positive salt anomaly located in the northern ttegat will increase the rate of current in the er layer through the Kattegat; when the maly shifts to the southern part of this water, will decrease the rate of current in the lower er.

To all essentials, the phase difference found above must be the one that is caused by this movement of water. This goes well with the fact that it varies in the same way as the solenoid field calculated by Jacobsen 1913. p. 51[4]).

Thus we notice that *the phase difference recorded between the two localities depends, principally, on the time required for the transport of an anomaly from one place to another, but it may also be influenced more or less by the degree to which the monthly means of salinity show a conformity of variation on account of contemporary changes in the strength of current and on account of deep sea waves.*

c. *The annual change of phase difference for occurrence of salinity anomalies at various lightvessels.*

Direct observations of the current in the lower layer were carried out from the Schultz Grund L. V. from 1910 to 1916. For certain reasons, however, the variations of current cannot be considered expressive of changes of the water movement through the section Djursland — Sjællands Odde; and they are even less representative of the annual variation in the strength of current.

Firstly, the Schultz Grund Lightvessel is moored on the edge of a shallow bank, and there is no equal representation of in- and outgoing currents in this place.

As calculated by Jacobsen 1925, p. 44[1]) the average quantity of water passing the section Refsnæs — Gyllingnæs during one month below 12·5 m. depth may be expressed by 2·49 $s_u$ + 15·5 where $s_u$ is the resulting current at the Schultz Grund (in cm./sec.) within these depths, and thus we find a poorer representation of the outgoing than of the ingoing current at the Schultz Grund.

As the ratio between frequency and strength of in- and outgoing current changes in course of the year, we are not allowed to conclude that a given resulting current observed at the Schultz Grund is, at any season, representative of the same quantity of water.

Secondly, the same current observed at a certain depth at different seasons is not representative of the same quantity of water passing in the lower layer because the depth of the boundary between upper and lower layer is subject to changes. For practical reasons Jacobsen's calculations are based on the existence of a fixed boundary between upper and lower layer. This boundary, however, will show a tendency of sinking when the water of the upper layer is pressed southwards by strong westerly winds and of rising if the water is forced out by easterly winds. In the first case the ingoing movement is distributed not over the portion considered as the upper layer in the calculation only but also over part (or the whole) of the lower layer; in the second case the outgoing

movement in the real upper layer affects a part only of the quantity included in the calculation (cp. Jacobsen, 1913, p. 66[4]). In other words: the calculated resulting (outgoing) current of the upper layer (the difference between out- and ingoing current in the layer down to 12·5 metres depth) is too strong as the fact that the boundary between upper and lower layers is constantly changing has not been considered in this calculation. In the same way we find the calculated resulting (ingoing) current of the lower layer to be stronger than shown by a calculation considering the changing boundary between the two layers.

In spite of these reservations, however, the annual variation in the strength of the ingoing current as found by direct observations must be supposed to be expressive of the annual variation of the water movement in the lower layer through the section although the difference between winter and summer is hardly as great as found by Jacobsen's method.

But this annual variation is contrary to that obtained from a calculation of the time required for a salt anomaly to spread from the Skaw to the Schultz Grund.

If the quarterly mean of salinity at the Skaw is correlated with the salinity at the Anholt Knob, Bottom, in the same and the following quarters we find the coefficients represented in Table 6.

## Table 6.

Quarterly means of salinity at Skagens Rev, Bottom, correlated with salinity at Anholt Knob, Bottom, in the same quarter, and in quarters displaced 1—3 months, respectively.

| Salinity, Anholt Knob, in | Salinity, Skagens Rev, in | | | |
|---|---|---|---|---|
| | 1st quarter | 2nd quarter | 3rd quarter | 4th quarter |
| same quarter ..... | 0.22 | **0·35** | **0·48** | —0·02 |
| quarter, 1 month later .. | **0·41** | **0·34** | **0·34** | **0·28** |
| quarter, 2 months later . | **0·47** | 0·26 | 0·09 | 0·09 |
| quarter, 3 months later . | 0·34 | 0.07 | —0.24 | 0.17 |

This calculation gives the same annual variation as found by examining the phase difference between the occurrence of the anomalies at the Skaw and the Schultz Grund and between the occurrence of the temperature anomalies at the Skaw and the Anholt Knob (Table 8). The phase difference between the occurrence of the anomalies at the Skaw and at Anholt is smallest in summer (less than 1 month) and greatest in winter (1—2 months).

However, at the Anholt Knob and the Schultz Grund, Bottom, the phase difference recorded between the appearance of the anomalies is greatest in summer (about 1 month) and smallest in winter (less than 1 month); this is represented in Table 7.

## Table 7.

Quarterly means of salinity at Anholt Knob, Bottom, correlated with salinity at Schultz Grund, Bottom, in the same quarter, and in quarters displaced 1—2 months, respectively.

| Salinity, Schultz Grund, in | Salinity, Anholt Knob, in | | | |
|---|---|---|---|---|
| | 1st quarter | 2nd quarter | 3rd quarter | 4th quarter |
| same quarter ..... | **0·45** | 0·44 | 0·52 | **0·5** |
| quarter, 1 month later .... | 0·40 | **0·54** | **0·60** | **0·5** |
| quarter, 2 months later ... | 0·36 | 0·18 | 0·36 | 0·2 |

Consequently, the annual variation of the strength of the resulting current in the lower layer, as recorded by direct observations of current, corresponds to the one found in the phase difference between the occurrence of a salt anomaly at the Anholt Knob and at the Schultz Grund, Bottom.

*Thus, there is hardly any doubt that the rate of the resulting current in the lower layer of the southern Kattegat reaches its maximum in winter.* However, *in the northern Kattegat the maximum seems to occur in spring, summer and autumn, the minimum in winter.* The highest development was, *a priori*, likely to occur in spring, summer and autumn, the dynamic field being strongest during these seasons. According to Jacobsen, 1913, p. 50[4]), the solenoid field of the northern Kattegat reaches its maximum in April, May, June and October, partly also in August and September, the minimum occurring in December, January and February. The limitation of the strong ingoing summer current of the lower layer to the northern deeper parts of the Kattegat must, within this area, result in a more intense admixture of lower layer water to the water of the upper layer in summer

## Table 8.

Monthly means of temperature at Skagens Rev, Bottom, correlated with means of temperature at Anholt Knob, Bottom, in the same and the following months, respectively.

| Temperature Anholt Knob in | Temperature, Skagens Rev, Bottom, in | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
| same month ..... | 0·40 | 0·43 | 0·42 | 0·26 | **0·70** | **0·66** | **0·68** | **0·69** | **0·74** | **0·71** | 0·54 | 0·57 |
| 1 month later ..... | **0·69** | **0·98** | **0·81** | **0·69** | 0·55 | 0·27 | 0·42 | 0·40 | **0·70** | **0·83** | **0·69** | **0·76** |
| 2 months later ..... | 0·52 | **0·80** | **0·85** | 0·57 | 0·07 | 0·05 | —0·16 | 0·31 | 0·31 | 0·58 | 0·52 | 0·53 |
| 3 months later ..... | 0·12 | 0·28 | 0·33 | 0·10 | | | | | | | | |

(I)

## Table 9.

thly means of Surface-salinity at Schulz Grund correlated with monthly means at Skagens Rev in the preceding, the same and the following months, respectively.

| alinity Skagens Rev in | Salinity, Schultz Grund, in | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
| onths previous .. | —0·25 | —0·25 | *—0·54* | *—0·32* | *—0·43* | *—0·44* | —0·05 | 0·11 | —0·05 | —0·18 | *—0·32* | *—0·30* |
| onth previous ... | **0·31** | 0·10 | —0·13 | —0·03 | —0·21 | —0·09 | **0·32** | **0·60** | 0·07 | **0·33** | 0·12 | 0·12 |
| e month ..... | **0·58** | **0·61** | **0·62** | **0·69** | **0·45** | **0·74** | **0·79** | **0·71** | **0·83** | **0·72** | **0·75** | **0·33** |
| onth later ..... | **0·49** | 0·11 | **0·30** | **0·46** | **0·46** | **0·45** | **0·48** | 0·02 | 0·24 | 0·20 | 0·11 | **0·33** |
| onths later ..... | 0·15 | 0·05 | 0·08 | 0·02 | —0·03 | **0·38** | 0·09 | 0·04 | —0·07 | 0·01 | —0·03 | 0·17 |
| onths later ..... | —0·20 | 0·09 | —0·04 | 0·00 | 0·21 | 0·15 | 0·01 | —0·11 | 0·13 | —0·20 | —0·08 | 0·01 |

autumn than in winter, whereas the most nsive mixing of the Belt Sea and the Sound s place in winter. This is because the strong ow of the summer must return as outflow in upper layer, and the larger the percentage ixture of water from the lower layer to that he upper one, the higher the salinity of the er layer within this area. That this is actually case appears from the way in which the salinity he upper layer decreases northwards through Kattegat during the different seasons of the r (cp. Figure 2 and the charts of average nity published by Jacobsen, 1908[8]).

In view of the fact that the inflow in the hern Kattegat varies to a considerable degree pendently of the inflow at the entrance of the Sea it is easily understood why it is impossible stablish a correlation between observed current salinity of the lower layer at the Schultz nd.

### The moving of the water bodies in the upper layer.

If we correlate the monthly mean salinity of surface water at the Schultz Grund L.V. with of the surface water at the Skagens Rev L.V. the previous, the same, and the following ths, we find that there is, at all seasons, a distinct connexion between the salt at the Schultz Grund and the salt at the Skagens Rev in the same month (Table 9). As demonstrated by Jacobsen the current of the upper layer is highly influenced by the wind which causes a simultaneous movement of the isohalines all over the area. A contributory cause is the fact that a salt anomaly of the upper layer spreads most rapidly from the Schultz Grund to the Skagens Rev on account of the rapidity of current. *Thus we note that the surface salinity of the Kattegat is very homogeneous (shows a distinct "continuity")* within the same month. In summer there is an insignificant positive correlation between salinity at the Schultz Grund and at the Skaw in the previous month and both in summer and winter between salinity at the Schultz Grund and at the Skaw in the following month. The positive correlation between the salinities at the Schultz Grund and at the Skaw in the previous and the following months in summer is due to the fact that the salinity does not change very much (shows a considerable "stability") during this season (cp. Table 18). In winter, however, when the stability of the salinity is very small, the positive correlation with the salinitv of the following month must be ascribed to the fact that *the water moves more slowly during this period*, causing that a certain anomaly takes a longer time to spread from the Schultz Grund to the Skaw than in summer. In summer an anomaly at surface occurs practically at the same time all over the Kattegat.

## Table 10.

thly means of salinity at Skagens Rev, Bottom, correlated with means of salinity in Kattegat, Surface, in the preceding, the same and the following months, respectively.

| Salinity Kattegat, Surface, in | Salinity, Skagens Rev, Bottom, in | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
| eding month .... | 0·16 | 0·18 | 0·04 | 0·10 | 0·28 | —0·19 | 0·04 | —0·11 | —0·18 | 0·00 | 0·20 | 0·28 |
| e month ..... | **0·50** | —0·07 | *—0·50* | *—0·49* | *—0·35* | *—0·51* | *—0·32* | *—0·44* | *—0·40* | *—0·40* | 0·03 | *—0·41* |
| onth later ..... | 0·34 | —0·20 | 0·00 | —0·30 | —0·02 | —0·16 | —0·25 | 0·27 | —0·12 | 0·15 | 0·00 | —0·16 |
| onths later ..... | —0·06 | —0·05 | 0·24 | 0·35 | —0·06 | 0·10 | 0·03 | 0·33 | **0·27** | 0·16 | 0·07 | 0·08 |
| onths later ..... | —0·24 | **0·35** | **0·47** | **0·60** | —0·01 | 0·06 | **0·33** | **0·39** | 0·19 | **0·19** | **0·18** | —0·09 |
| onths later ..... | 0·10 | 0·16 | 0·27 | 0·26 | **0·31** | —0·04 | 0·14 | 0·14 | 0·19 | 0·02 | 0·00 | 0·04 |

## Table 11.

Monthly means of salinity at Schultz Grund, Bottom, correlated with means of salinity in Kattegat Surface, in the preceding, the same and the following months, respectively.

| Salinity Kattegat, Surface in | Salinity, Schultz Grund, Bottom, in Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 months previous .. | 0·09 | —0·06 | 0·15 | 0·12 | —0·04 | —0·42 | 0·23 | 0·00 | 0·17 | 0·29 | 0·05 | 0·1 |
| 2 months previous .. | *—0·60* | —0·19 | —0·31 | —0·36 | —0·14 | —0·11 | —0·22 | —0·19 | —0·16 | 0·21 | —0·33 | —0·1 |
| 1 month previous ... | *—0·62* | *—0·59* | *—0·52* | *—0·56* | *—0·42* | *—0·45* | *—0·62* | *—0·54* | *—0·61* | *—0·61* | *—0·76* | *—0·5* |
| same month ..... | —0·18 | —0·31 | —0·03 | 0·22 | 0·07 | —0·05 | *—0·43* | *—0·50* | —0·07 | *—0·41* | —0·11 | 0·2 |
| 1 month later ..... | —0·23 | 0·14 | **0·40** | **0·45** | **0·55** | **0·41** | —0·16 | 0·12 | 0·24 | 0·07 | **0·39** | 0·1 |
| 2 months later ..... | —0·03 | 0·26 | **0·34** | **0·41** | **0·51** | 0·12 | **0·38** | 0·16 | **0·30** | **0·30** | 0·24 | 0·2 |
| 3 months later ..... | 0·14 | 0·08 | 0·08 | 0·20 | 0·28 | 0·02 | —0·04 | 0·05 | 0·14 | 0·07 | 0·19 | 0·1 |

### 3. The interference between upper and lower layer.

a. *Connexion between salinity at surface and salinity at bottom in the same and the following months.*

By means of the calculations of correlation we are further able to follow the interference between the water bodies of the upper and lower layer. If we correlate the salinity at the surface of the Kattegat (the mean salinities at the Schultz Grund, the Anholt Knob and the Skaw) with the salinity at the Skagens Rev, Bottom, we get the coefficients presented in Table 10. On account of the continuity in the surface layer of the Kattegat shown above the mean salinities at the three lightvessels were used in this calculation.

Table 11 gives the corresponding coefficients of correlation between salinity at the Schultz Grund, Bottom, and salinity at the surface of the Kattegat.

When the salinity of the surface is correlated with the salinity at the Schultz Grund, Bottom, in the following month and at the Skagens Rev in the same month respectively, we get significant negative correlations. Such a negative correlation might be due to two causes:

(A) It may be the consequence of the convection changing from year to year; years of smaller convection yielding a comparatively low salinity at the surface and a comparatively high one at the bottom while years of large convection show the reverse;

(B) or it may be a consequence of the fact that the strength of the outflow, which can be measured by the salinity of the upper layer, determines the salinity of the lower one during the immediate future because a low salinity of the upper layer strengthens the dynamic field, thus causing a comparatively strong inflow in the lower layer and, consequently, an increased salinity of the latter.

However, an examination of the co-variation between salinity at bottom and surface at the same lightvessel gives information on the causality.

## Table 12.

Quarterly means of surface-salinity at Schultz Grund correlated with salinity at Schultz Grund Bottom, in preceding quarters displaced 4 months in the same quarter, and in following quarters displaced 1 to 7 months, respectively.

| Bottom-Salinity in quarters displaced | Salinity at surface in 1st quarter | 2nd quarter | 3rd quarter | 4th quart |
|---|---|---|---|---|
| —4 months ... | 0·09 | 0·16 | 0·21 | 0·0 |
| —3 months ... | 0·22 | 0·29 | **0·40** | **0·3** |
| —2 months ... | **0·40** | **0·49** | 0·20 | **0·3** |
| —1 month .... | 0·21 | **0·53** | —0·24 | 0·2 |
| not displaced ... | —0·19 | 0·40 | *—0·36* | —0·2 |
| + 1 month .... | *—0·50* | —0·22 | *—0·38* | *—0·5* |
| + 2 months ... | *—0·63* | *—0·30* | —0·17 | *—0·3* |
| + 3 months ... | *—0·61* | —0·05 | —0·03 | —0·0 |
| + 4 months ... | *—0·39* | —0·02 | 0·03 | 0·1 |
| + 5 months ... | —0·28 | —0·11 | 0·00 | 0·1 |
| + 6 months ... | —0·18 | *—0·33* | —0·12 | 0·0 |
| + 7 months ... | —0·15 | *—0·32* | 0·00 | —0·0 |

Table 12 and Fig. 5 illustrate correlations between quarterly mean salinities at bottom and surface at the Schultz Grund L.V.

We find that a salinity anomaly at surface is observed in most months prior to the reverse anomaly in the bottom water. If the changing convection were the cause of the negative correlation the opposite anomalies must necessarily occur simultaneously at the same lightvessel. This is not the case: a marked difference of phase is found to exist, so that a certain anomaly at surface will be followed, in the immediate future, by the reverse anomaly at bottom; thus the principal cause must be supposed to be the fact that *the strength of the outflow (or the higher or lower salinity in the upper layer of the Kattegat) determines the reactive inflow of more saliferous water in the lower layer of the Kattegat.*

It appears from Tables 12 and 13 (as from Tables 10 and 11) that the reverse anomalies in the summer months show a tendency of occurring

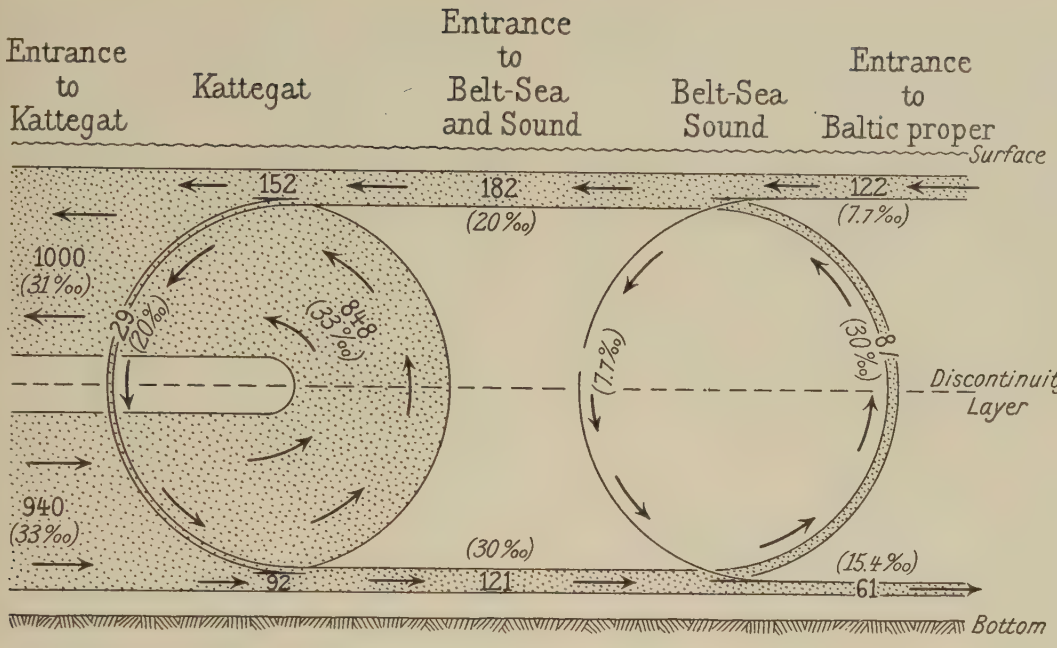


Fig. 4.

rchange of water in Kattegat and the Belts, calculated from the formulae of M. Knudsen. The breadth of dotted areas denotes the amount of water in ‰ of the amount passing from the Kattegat to the Skagerak.

## Table 13.

arterly means of surface-salinity at Skagens k L.V. correlated with quarterly means of salinity bottom at the same light-vessel in the preced-, the same, and the following quarters (cp. Table 12).

| Bottom-salinity quarters displaced | Salinity at surface in 1st quarter | 2nd quarter | 3rd quarter | 4th quarter |
|---|---|---|---|---|
| 1 month ..... | 0·09 | —0·05 | —0·13 | 0·13 |
| displaced ..... | —0·05 | —0·22 | —0·14 | 0·06 |
| 1 month ..... | 0·13 | —0·01 | 0·08 | 0·10 |
| 2 months ..... | —0·15 | 0·05 | 0·21 | 0·08 |
| 3 months ..... | 0·29 | 0·26 | 0·17 | —0·04 |
| 4 months ..... | 0·23 | 0·23 | 0·17 | —0·05 |

ultaneously at surface and at bottom. In sum-r, when generally the upper and lower layer sharply separated by a discontinuity layer, simultaneous occurrence of reversed anomalies surface and bottom is also a consequence of the ference of the convection from year to year ing an active cause of the anomalies. In autumn d winter both the Skaw and the Schultz Grund w a tendency of positive correlations between ultaneous anomalies at surface and bottom, ich must be ascribed to the lack of a sharp tinction between upper and lower layer during is period, most of the water column moving in out as an entirity, so that positive or negative anomalies respectively occur simultaneously at surface and bottom.

In Table 13 the quarterly means of surface-salinity at Skagens Rev L.V. are compared with quarterly means of bottom-salinity at the same light-vessel. In these quarterly means the negative correlations between salinity at surface and bottom in the same months almost disappear.

On the other hand a pronounced tendency of positive correlations with bottom salinity in the subsequent period appears. It may seem, therefore, that the surface water when mixing with the water of the Jutland current in the Skagerak directly influences its salinity perceptibly, if to a small degree only.

b. *Connexion between salinity at bottom and salinity at surface in the following months.*

We have seen above that the admixture of water from the upper layer of the Kattegat to that of the lower layer cannot be traced in the salinity of the latter. As will appear when studying Fig. 4 the quantity of water passing from the upper to the lower layer of the Kattegat constitutes a very small part of the lower layer, and so we cannot expect to be able to establish a connexion of this kind. It appears from Figure 4, however, that the upper layer of the Kattegat receives a very large quantity of water from the lower layer, and it is thus an obvious conclusion that a certain salt anomaly can

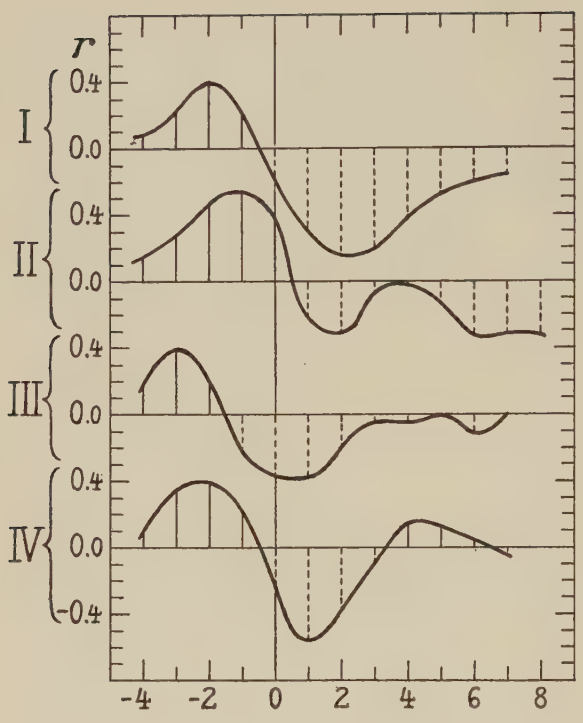


Fig. 5.
Correlation between quarterly means of bottom and surface salinity at Schultz Grund. (cp. Table 12).

be followed from the lower to the upper layer, coincidently with this admixture.

That this is really the case appears from Table 10. A distinct correlation is noted to exist between the salinity at the Skagens Rev, Bottom, in February—March—April and the surface salinity 2 or 3 months later, and it is also possible to establish a positive correlation between the salinity at the Skagens Rev, Bottom, in July—August—September (to a minor degree in the following months) and the surface salinity 2 or 3 months later.

We found above that the water transport in the lower layer through the Kattegat from the Skaw to the Schultz Grund in summer lasts no more than about 1 month. That the influence on the salinity of the surface is observed so much later is a natural consequence of the comparatively small intensive mixing of the two layers of this water in summer.

As to the summer and winter months only the most insignificant connexion can be established.

The same influence of the salinity of the lower layer on that of the upper layer is found by calculating the correlation between the salinity at the Schultz Grund, Bottom, and at the surface of the Kattegat during the following period (Tables 11 and 12). Here, too, *we notice a marked influence of the salinity of the bottom layer on that of the surface layer in spring. Further, the salinity of the lower layer seems to affect the upper layer through the lower layer inflow passing the Schultz Grund in November—December.* The phase difference between bottom and surface is here about 1 or 2 months.

If we correlate the salinity at Skagens Rev, Bottom, with the salinity at the Schultz Grund, Surface, a longer time is found to pass before a positive correlation occurs than in the connexion examined above, which corresponds to the fact that the water movement, expressed by the positive correlation, in the case considered takes place principally through the lower layer from the Skaw to the Schultz Grund and from here to the surface.

## Table 14.

Monthly means of salinity at Schultz Grund, Bottom, correlated with surface temperatures in Kattegat in the same, and the following months, respectively.

| Surface-temperature in | Salinity, Schultz Grund, Bottom, in | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec |
| same month ..... | 0·08 | —0·23 | —0·10 | —0·28 | —0·06 | 0·02 | **0·38** | **0·54** | **0·31** | 0·06 | 0·21 | 0·2( |
| 1 month later ..... | 0·03 | —0·03 | —0·02 | *—0·31* | —0·15 | —0·25 | 0·29 | 0·14 | —0·10 | 0·24 | 0·10 | **0·33** |
| 2 months later ..... | —0·08 | 0·18 | —0·15 | —0·26 | —0·04 | —0·06 | 0·13 | —0·08 | 0·01 | 0·14 | **0·44** | **0·32** |
| 3 months later ..... | —0·11 | —0·03 | —0·02 | —0·09 | —0·10 | —0·15 | —0·01 | —0·23 | 0·08 | 0·13 | **0·42** | 0·15 |
| 4 months later ..... | 0·04 | 0·02 | 0·14 | 0·01 | —0·13 | 0·11 | 0·08 | —0·06 | —0·04 | 0·25 | 0·22 | 0·15 |

## Table 15.

Monthly means of temperature at Schultz Grund, Bottom, correlated with surface temperatures in Kattegat, in the same, and the following months, respectively.

| Surface-temperature in | Temperature, Schultz Grund, Bottom, in | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
| same month ..... | 0·23 | —0·24 | 0·07 | 0·05 | 0·02 | —0·02 | *—0·32* | *—0·39* | 0·21 | 0·08 | **0·38** | 0·21 |
| 1 month later ..... | —0·08 | —0·08 | 0·03 | 0·01 | —0·09 | 0·36 | —0·16 | *—0·30* | 0·30 | —0·18 | **0·30** | **0·35** |
| 2 months later ..... | —0·03 | 0·06 | 0·07 | 0·03 | 0·17 | —0·06 | —0·11 | 0·04 | —0·10 | —0·13 | **0·50** | 0·26 |
| 3 months later ..... | 0·07 | 0·16 | 0·11 | 0·20 | 0·04 | 0·19 | 0·05 | 0·12 | —0·22 | 0·11 | **0·36** | 0·22 |

Of course the admixture varies highly from r to year, and the time elapsing from the urrence of a certain salt anomaly in the lower er till its maximum influence on the surface inity is observed, is in some years shorter than others. We get a clearer picture of the con- ion if we correlate the quarterly means at tom and surface (Table 12, and Figure 5) than ve correlate the monthly means. In other words surface salinity is negatively correlated with salinity at bottom in the immediate future and itively correlated as regards the time im- diately preceding. At the Skagens Rev L.V. the itive correlation outweighs in the annual mean correlation between the annual mean of salt at tom and surface, being $r = 0{\cdot}651$; at the Schultz nd the two effects counterbalance each other, correlation between salt at bottom and surface ng $r = 0{\cdot}079$.

*The influence of the lower layer on the surface temperature of the Kattegat.*

If we correlate salinity and temperature respec- ly at the Schultz Grund, Bottom, with the face temperature of the Kattegat (mean of Ska- s Rev, Anholt Knob and Schultz Grund), we the values in Tables 14 and 15. In accordance h the connexion recorded above between salinity bottom and at surface, *we here find a "signi- nt" correlation between the temperature and nity at the Schultz Grund, Bottom, and the perature of the surface in spring and early mer as well as in autumn.* As might be ex- ted the correlation between salt and temperature egative in early summer and positive in autumn. e connexion between salinity at bottom and perature at surface was formerly discussed by A. C. Johansen[9]), and A. C. Johansen and Aage J. C. Jensen[10]), 1926.

The connexion found between salinity and temperature at bottom and winter-temperature at surface is of considerable biological interest because, i. a., it offers a possibility of forecasting the temperature of the coldest months, which are of principal biological importance; and furthermore it is of practical value, i. a., for the possible forecasting of icy winters.

d. *Connexion between simultaneous variations of salt and temperature in the separate localities.*

As far as the surface is concerned the connexion between salt and temperature appears from Table 16; in Table 17 we find in centidegrees the

**Table 16.**

Correlation between contemporary monthly means of salinity and temperature at the surface of Kattegat.

| | | | |
|---|---|---|---|
| Apr. | $r = -0{\cdot}05$ | Oct. | $r = 0{\cdot}23$ |
| May | „ —0·56 | Nov. | „ 0·20 |
| June | „ —0·90 | Dec. | „ 0·44 |
| July | „ —0·63 | Jan. | „ 0·54 |
| Aug. | „ —0·64 | Feb. | „ 0·54 |
| Sep. | „ —0·34 | Mar. | „ 0·41 |

difference between the temperatures of surface water and bottom water. A positive correlation between salt and temperature is found in months when the bottom water is warmer than the surface

[10]) A. C. Johansen and Aage J. C. Jensen: Remarks on the influence of the currents in the waters about Denmark and neighbouring countries. — Physiological papers dedicated to Professor August Krogh. Copenhagen. 1926.

**Table 17.**

relation between contemporary monthly means of salinity and temperature at the bottom compared with difference in temperature (°C) between surface and bottom[1]).

| | | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| gens | $r =$ | —0·10 | 0·56 | 0·45 | 0·12 | —0·16 | —0·41 | —0·32 | —0·24 | —0·37 | —0·37 | —0·30 | 0·11 |
| L.V. | diff. | —1·8 | —1·5 | —1·5 | —0·1 | 2·0 | 3·9 | 3·9 | 2 2 | 1·3 | 0·2 | —0·8 | —1·7 |
| ultz | $r =$ | 0·86 | 0·75 | 0·56 | 0·42 | 0·19 | —0·13 | —0·77 | —0·82 | —0·47 | —0·27 | —0·50 | 0·65 |
| d L.V | diff. | —3·0 | —2·6 | —2·1 | 0·2 | 4·3 | 8·2 | 9·0 | 6·3 | 2·4 | —0·9 | —2·8 | —3·5 |

1) From: Mean values of observations from Danish light-vessels. — Publikationer fra Det danske meteorologiske Institut. enhavn. 1933.

**Table 18.**

nthly means of surface-salinity of Kattegat correlated with mean-salinity at surface 1 and 2 months later, respectively (stability of salinity at surface).

| Salinity | Salinity in Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nonth later ..... | **0·47** | 0·03 | 0·28 | 0·18 | **0·39** | **0·56** | **0·62** | 0·02 | **0·31** | 0·22 | 0·12 | **0·33** |
| months later ..... | —0·09 | —0·23 | —0·22 | —0·22 | 0·06 | 0·24 | 0·03 | —0·12 | —0·21 | —0·25 | —0·20 | —0·12 |

## Table 19.

Monthly mean of surface-temperature of Kattegat correlated with mean temperature at surface 1, 2, and 4 months later, respectively (stability of surface-temperature).

| Temperature | Temperature in Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | De |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 month later ..... | **0·63** | **0·60** | **0·84** | **0·69** | **0·51** | **0·56** | **0·73** | **0·62** | **0·37** | **0·53** | **0·51** | **0·4** |
| 2 months later ..... | **0·40** | **0·56** | **0·54** | **0·40** | **0·39** | **0·44** | **0·46** | 0·21 | 0·26 | 0·24 | **0·37** | **0·3** |
| 3 months later ..... | **0·35** | **0·44** | **0·30** | **0·33** | **0·39** | **0·34** | 0·06 | 0·11 | 0·16 | 0·02 | 0·00 | —0·( |
| 4 months later ..... | **0·35** | 0·15 | 0·29 | 0·14 | 0·22 | 0·00 | —0·13 | 0·10 | 0·11 | 0·01 | —0·05 | 0·1 |

## Table 20.

Monthly means of air-temperature at Copenhagen (Landbohøjskolen)[1]) correlated with mean temperature of the air 1 and 2 months later, respectively (stability of air-temperature).

| Temperature | Temperature in Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | De |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 month later ..... | **0·62** | **0·45** | **0·44** | **0·37** | 0·27 | 0·28 | **0·63** | **0·53** | **0·40** | 0·16 | 0·26 | 0·2 |
| 2 months later ..... | **0·34** | **0·49** | 0·15 | 0·10 | 0·23 | **0·32** | 0·20 | 0·15 | 0·17 | 0·04 | —0·08 | 0·( |

[1]) From Meteorologisk Aarbog. København.

## Table 21.

Monthly means of salinity at Schultz Grund, Bottom correlated with salinity at the same position 1 and 2 months later, respectively (stability of salinity at bottom).

| Salinity | Salinity in Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | De |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 month later ..... | 0·18 | **0·36** | **0·42** | **0·40** | 0·12 | **0·32** | **0·43** | **0·48** | —0·04 | **0·63** | 0·23 | 0·0 |
| 2 months later ..... | 0·16 | 0·12 | —0·12 | 0·18 | 0·02 | 0·03 | 0·05 | —0·07 | —0·24 | —0·04 | —0·20 | —0·1 |

## Table 22.

Monthly means of temperature at Schultz Grund, Bottom, correlated with temperature at the same position 1 and 2 months later, respectively (stability of temperature at bottom).

| Temperature | Temperature in Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | De |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 month later ..... | **0·50** | **0·57** | **0·64** | **0·84** | **0·77** | **0·56** | **0·46** | **0·45** | **0·40** | 0·23 | **0·48** | **0·5** |
| 2 months later ..... | 0·23 | **0·30** | **0·33** | **0·56** | 0·25 | **0·33** | 0·17 | 0·23 | 0·06 | **0·43** | 0·25 | **0·3** |

water; when the bottom water is colder, the correlation is a negative one. Apparently, the higher or lower degree of admixture is of very great importance to the salinity and temperature of the surface water both in summer and in winter.

Table 17 represents the correlation between salinity and temperature at the bottom at the Skaw and the Schultz Grund respectively, and we notice that the co-variation is much more pronounced at the Schultz Grund than at the Skaw, but otherwise the annual run of the connexion is fairly the same with a positive correlation in winter and a negative one in summer. We further note that the changes of the correlation coefficient throughout the year do not correspond directly to the changing difference between the temperatures of bottom water and surface water but occur somewhat later: at the Skaw about a fortnight later, at the Schultz Grund some 6 weeks later in spring and about 15 days later in autumn. This seems to indicate that the co-variation between temperature and salinity at bottom is less dependent on the vertical convection than on the inflow.

e. *Stability of salinity and temperature.*

In winter (October—April) there is a very inferior stability in the surface salinity (cp. Table 18), indeed, there is a tendency of changing from a positive to a negative salinity anomaly, and *vice versa*, from one month to another. This is an obvious consequence of the fact that a certain salt anomaly in the upper layer is followed, in the immediate future, by the reverse anomaly, arising in the lower layer and spreading from there to the upper layer.

In summer (June—September) the surface salinity shows a greater stability, corresponding to the fact that an anomaly takes a longer time to spread from bottom to surface at this season of the year.

It is a well-known fact that changes in the perature of the sea take place very slowly on ount of the high specific heat of the water. course of this co-variation between the surface perature of the Kattegat in one month and in following ones appears from Table 19.

More particularly in the spring and early mmer we find a very considerable stability of perature; in late summer, autumn and early ter it is considerably less pronounced. The

**B. Moving of anomalies of salinity from the Kattegat to the Baltic.**

**1.** Connexion between salinity and current at Drogden and Gedser and salinity in the lower layer of the Baltic.

Observations of salinity from the lower layers of the Baltic originate exclusively from the cruises of investigation. Observations from Swedish and

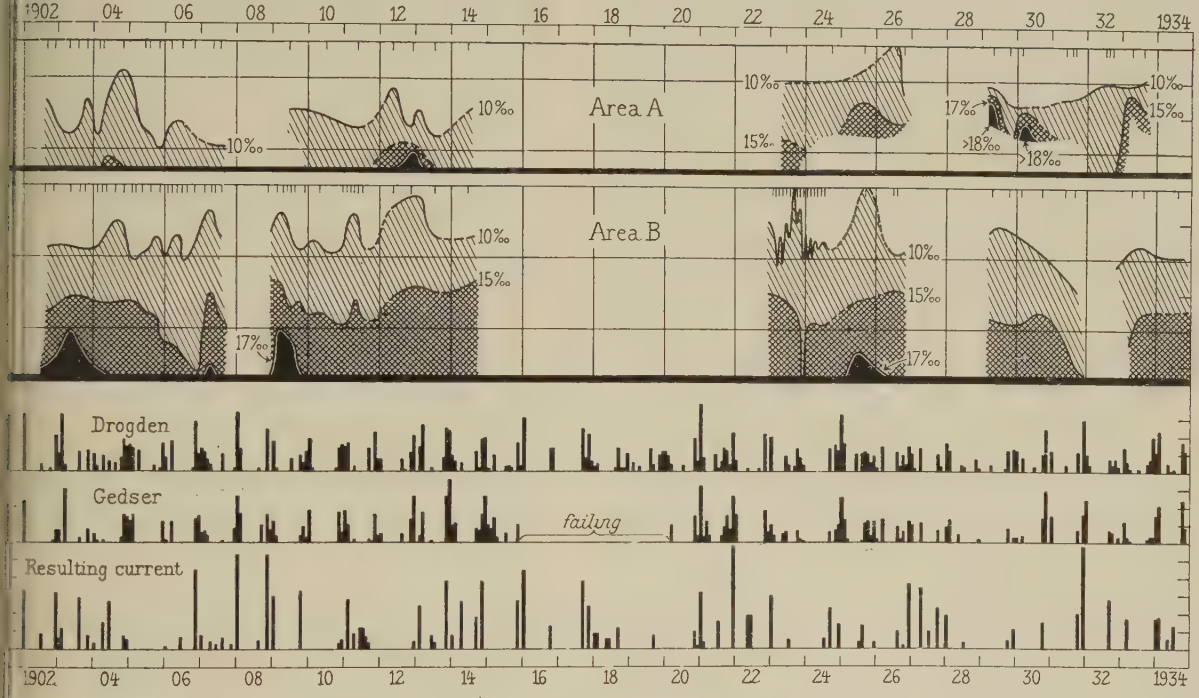


Fig. 6.

ation of salinity at Bornholm in Areas A and B, respectively, (chart Fig. 1) compared with monthly mean salinities more than 10 ‰ at Drogden and Gedser, and observed resulting ingoing current at Drogden (Frequency (%) × velocity es per hour)). In the figure resulting ingoing currents should be added for August 1919 (strength 24), Nov. 1922 (19), Oct. 1923 (11), July 1933 (26) and Oct. 1934 (29).

le shows that it is almost impossible to forecast winter temperature of the surface water from peratures more than one month in advance; winter temperature, however, is very constant, l its influence is felt until late in spring.

As might have been expected the temperature the atmosphere is not so stable but its annual iation is nearly the same as that of the water . Table 20)*).

Corresponding to the inferior stability of the inity at surface (in the upper layer) a poor bility only is to be found in the salinity of the tom water of the Kattegat (see Table 21).

Especially in spring the temperature of the tom water of the Kattegat shows a very high gree of stability (cp. Table 22).

*) Meteorologisk Aarbog. — København.

German lightvessels only go well into the upper layer, some of the former reaching a depth of 40 m. The observations of the period 1902—07 were dealt with by J. Gehrke[11]). Up to the beginning of 1911 regular quarterly observations were carried out; in 1923 and the first half of 1924 weekly observations are to hand from the area S. E. of Christiansø, but otherwise observations are rather scanty and give a very imperfect idea of the fluctuations of salinity, temperature and oxygen content.

In Figure 6 these observations are combined partly for the areas N. W. of Bornholm, partly for the Bornholm Basin. In the same figure we find the monthly mean salinity at Drogden and Gedser

11) Gehrke: Beiträge zur Hydrographie des Ostseebassins. — Publications de Circonstance. No. 52. 1910.

and the monthly mean of observed resulting current.

The variations of salinity in the lower water layers of the Baltic to some extent follow the variations at Drogden and Gedser, so that prior to a high salinity in the Baltic we always find a high salinity at the entrances to the Baltic but, on the other hand, a high salinity in the latter localities is not always followed by a high salinity in the Baltic.

However, neither the salinity nor the observed ingoing current at Drogden and Gedser can be used as direct measures of the quantity of salt water carried into the Baltic, for it often happens that a strong inflow is immediately succeeded by a vigorous outflow which at once removes part, or practically the whole, of the quantity of salt carried across the barrier by the ingoing current.

Characteristic and instructive examples are the changes of current and salinity in the winter of 1904—05 when, according to G e h r k e, no inflow was observed in the Bornholm Basin, and in the winter of 1902—03 when a vigorous inflow took place.

In the winter of 1904—05 current and salinity at Drogden were as follows:

| | Ingoing current Frequency (in %) | Resulting current × strength (In nautical miles per hour). | Monthly mean salinity in ‰ Surface | Bottom |
|---|---|---|---|---|
| Aug. 1904 | 42·0 | 10·8 outg. | 11·0 | 11·9 |
| Sep. „ | 18·9 | 37·9 „ | 8·3 | 8·6 |
| Oct. „ | 58·5 | 4·2 „ | 11·5 | 12·8 |
| Nov. „ | 54·6 | 7·6 ing. | 13·5 | 14·4 |
| Dec. „ | 53·3 | 6·3 „ | 12·8 | 14·0 |
| Jan. 1905 | 58·5 | 3·9 outg. | 13·0 | 13·3 |
| Feb. „ | 37·4 | 18·6 „ | 12·7 | 13·6 |
| Mar. „ | 25·5 | 17·7 „ | 8·6 | 9·1 |

In October, when the ingoing current was strong though a little inferior to the outgoing one the salinity rose. In November and December the salinity was high on account of the vigorous inflow; these high salinities continued to occur not only in January when the inflow, although still vigorous, was surpassed by a strong outflow, but we also trace them in February when the strength of the inflow is very much inferior to that of the outflow.

On the other hand, during the very strong inflow of the winter of 1902—03 current and salinity were as follows:

| | Ingoing current Frequency (in %) | Resulting current × strength (In nautical miles per hour). | Monthly mean salinity in ‰. Surface | Bottom (6 m.) |
|---|---|---|---|---|
| Aug. 1902 | 15·6 | 16·8 outg. | 10·1 | 10·8 |
| Sep. „ | 23·4 | 23·8 „ | 9·8 | 10·4 |
| Oct. „ | 45·5 | 6·7 „ | 10·3 | 10·9 |
| Nov. „ | 27·9 | 32·1 „ | 10·1 | 11·8 |
| Dec. 1902 | 71·4 | 32·7 ing. | 13·9 | 15 |
| Jan. 1903 | 54·6 | 6·0 „ | 12·0 | 12 |
| Feb. „ | 58·8 | 11·5 „ | 16·3 | 17 |
| Mar „ | 39·0 | 23·0 outg. | 10·8 | 11 |
| Apr. „ | 19·8 | 33·8 „ | 9·6 | 10 |

The salinity was rising during the strong flow in December and still more so during inflow of February. In this year the salt was carried out again during the following months prevailing outflow, the salinity at once falling a rather low level.

Thus we note that neither of the follow characteristics: a high salinity, a strong ingo current or a resulting ingoing current for so months, is indicative of a vigorous flow into Baltic; but an examination of the variations *in se* of current and salinity will no doubt enable to decide whether an inflow has taken place or n

An attempt at stating the various inflows by t method has been made below.

For the years 1902—07 J. G e h r k e has giv a detailed analysis of the variations of salini temperature and oxygen content and has demo strated that these variations can be explained consequences of inflow and vertical convection.

Judging from the salinity at Drogden a Gedser and the observed current, strong inflo have prevailed during the following periods:

1902, January.
1902, December — 1903, February (G e h r k states strong inflow between the autun of 1902 and the spring of 1903).
1903, November ? (G e h r k e: considerable i flow between February and March 1904
1904, April, June? (G e h r k e: inflow of co water between May and August 1904).
1906, January, March (G e h r k e: considerab inflow between November 1905 and F bruary 1906).
1906, November (G e h r k e: strong inflow b tween November 1906 and Februa 1907).
1908, January, November.
1909, January, October.
1911, February, November.
1912, December.
1914, April, September, November.
1915, November.
1916, January.
1917, September, November.
1918, September.
1919, August.
1920, November.
1921, January, June, December.
1922, May, November.
1923, January.

924, September. January—February—March no observations. The oxygen content shows that no inflow has taken place during these months.
925, June, December.
926, August, December.
927, April, October.
928, January. February—March no observations. The oxygen content shows that an inflow has taken place during winter.
929, February—March no observations; the oxygen content shows that an inflow has taken place at this time.
929, October.
930, October, November.
931, October, December.
932, September, October.
933, March, July.
934, January, February, May, October.

*Oxygen content at bottom.* Scanty observations o oxygen content in the Bornholm Basin after confirm some of these inflows.

According to G e h r k e, the oxygen content of Bornholm Basin between August 1902 and l 1907 ranged between 0·1 and 5·5 cm.³ oximately, showing high but decreasing values 903—04, low values in 1905, and high values ie winter and spring of 1906—07.

924, on Jan. 12th the oxygen content was 1·1 cm.³
928, on July 8th the oxygen content was 3·3 and 2·9 cm.³
929, on Apr. 8th—13th the oxygen content was 7·6 cm.³ at bottom, but showed a minimum of 2·5 cm.³ at 80—85 metres depth.
930, on Sep. 19th the oxygen content was 1·8 cm.³
931, on May 22nd the oxygen content was 1·8 cm.³
933, on Apr. 5th—7th the oxygen content was 6·7—7·3 cm.³

These quantities of oxygen for April 1929 and l 1933 are exceedingly high and show that vigorous inflows must have taken place im-iately before.

However, observations are too few to enable us llow the inflows as could be done in the years —07, but they corroborate our deductions from nt and salinity at Drogden.

C o n n e x i o n b e t w e e n s a l i n i t y a n d e m p e r a t u r e a t D r o g d e n a n d s a l i n i t y a n d t e m p e r a t u r e i n t h e K a t t e g a t a n d t h e B a l t i c.

One might think that the inflow of some body ater showing a certain salt anomaly could be wed through the lower layer of the Kattegat Drogden by examining the monthly mean salinities. As will appear from Table 23, in which is represented the correlation between monthly means at the Anholt Knob, Bottom, and at Drogden, Bottom, no such connexion can be stated. We shall see later that the principal force influencing the salinity at Drogden is the current passing the Sound, but the salinity is not perceptibly influenced by a salinity anomaly found in the water of the lower current of the Kattegat.

## Table 23.

Quarterly means of salinity at Drogden, Bottom, correlated with means of salinity at Anholt Knob, Bottom, in the same quarter and in preceding quarters displaced 1 and 2 months, respectively. Calculated for the years 1909—34 (26 years).

| Salinity, Anholt Knob, in | Salinity, Drogden, in | | | |
|---|---|---|---|---|
| | 1st quarter | 2nd quarter | 3rd quarter | 4th quarter |
| quarter, 2 months before | 0·20 | 0·20 | 0·08 | 0·36 |
| quarter, 1 month before. | —0·01 | 0·22 | —0·03 | 0·30 |
| same quarter ..... | —0·13 | 0·17 | —0·17 | 0·12 |

## Table 24.

Monthly means of salinity at Drogden, Bottom, correlated with mean salinity at Anholt Knob, Surface, in the same and the following months. Calculated for the years 1909—34 (26 years).

| Salinity, Anholt Knob, 0 m., in | Salinity, Drogden. in | |
|---|---|---|
| | April | August |
| same month ..... | 0·18 | 0·16 |
| 1 month later ..... | **0·34** | **0·64** |
| 2 months later ..... | —0·10 | 0·42 |

We note from Table 24, however, in which the salinity at Drogden has been correlated with the salinity of the surface water of the Kattegat, that a distinct positive correlation exists between the salinity at Drogden and that of the Kattegat immediately after. The outflow through the Sound is distinctly reflected in the salinity of the surface water of the Kattegat.

## Table 25.

Quarterly means of surface-salinity at Christiansö correlated with salinity in the same quarter at Schultz Grund, Surface.

| | |
|---|---|
| 1st quarter | $r = 0{\cdot}03$ |
| 2nd „ | $r = 0{\cdot}06$ |
| 3rd „ | $r = 0{\cdot}82$ |
| 4th „ | $r = 0{\cdot}25$ |

A considerable positive correlation is found between the salinities at Christiansø and at the surface of the Kattegat in the summer only (see Table 25), and is found in that season on account of the fact that the variations of salinity, as will

be seen later, are highly influenced by the wind. A closer connexion exists in all seasons of the year between the variations of temperature which anywhere at the surface depend to a very considerable degree on the temperature of the atmosphere.

### C. Comparison between fluctuations in monthly or quarterly means of salinity from year to year and variations of observed current.

#### 1. The observations of current.

As demonstrated above, we find a good symbol of the inflow into the Baltic from the resulting current in connexion with the variations of salinity whereas salinity only or current alone cannot be used for this purpose.

In the following we shall look a little deeper into the connexion between salinity and observed current.

An excellent material for comparison is found in the Sound where the current at the Drogden Lightvessel, according to Jacobsen, may be considered representative of the current through this water.

It should be remembered, however, that monthly or quarterly means of salinity at Drogden give a measure of salinity corresponding to the mean salinity from surface to bottom in the upper plus the lower layer of the other waters. At Drogden the salinity is practically even from surface to bottom (6—8 metres), and so the bottom salinity has been chosen for this comparison.

Unfortunately, the current at Drogden (like the surface current at the rest of our lightvessels) is estimated only, and a look at the observations of current at once reveals the drawback of their liability to systematic errors on one point, viz., in the statements of the frequency of "hold-ups" of current. From 1898 to 1913, 0 % of "hold-ups" is reported to occur in one month only, the rest of the months showing up to 25 % and averaging about 10 % of "hold-ups". Between 1915 and 1930, however, 0 % of "hold-ups" occur in 37 months, the rest of them showing up to 6 %, in most cases 1 % only.

Of course we cannot say beforehand that this difference in the observations influences the calculated monthly mean of current, but the possibility exists, and furthermore other systematic errors in the observations may have been subject to changes in the progress of time. Therefore the observations of current cannot be used for the purpose of estimating secular changes of the in- and outflow. However, we are allowed to suppose that the possible errors influencing the calculated monthly mean current have been changing so slowly, that the variations from year to year can be applied as a measure of changes in the current at Drogden.

**Table 26.**

Quarterly means of observed current at Drogd correlated with salinity at Drogden, Bottom, in t same quarter. All currents are positive towar the Kattegat[1]).

| | Ingoing current | Outgoing current | Resulti curren |
|---|---|---|---|
| 1st quarter ..... | —0·67 | —0·22 | —0·5 |
| 2nd „ ..... | —0·27 | 0·03 | —0·2 |
| 3rd „ ..... | —0·77 | 0·03 | —0·5 |
| 4th „ ..... | —0·53 | —0·20 | —0·5 |

[1]) The depth at Drogden L. V. was 6 m. before 190 since then 8 m. The salinities at bottom have not bee corrected for this difference. Yet the correlation coefficie is about correct.

#### 2. Comparison between observed current and salinity.

In Table 26, the correlation coefficient is r presented between bottom salinity at Drogden an observed ingoing, outgoing, and resulting curre all reckoned positive in direction towards th Kattegat. It will be seen that the salinity, as migh be expected, shows a negative correlation bot with the ingoing and with the resulting current but no, or at any rate a small correlation onl with the observed outgoing current. However, th outflow is the most frequent current at Drogden and as we know from experience that an outgoing current causes a drop in salinity, the only explana tion of the fact mentioned is no doubt *that a outgoing current observed at Drogden is no representative of an outgoing current through th Sound.* In corroboration of this fact we find tha the smallest co-variation between observed outgoing current and salinity occurs in the second and third quarter, i.e. at the season of the year showing the strongest outflow. In the second quarter, when the inflow through the Sound is at its lowest, we find the loosest connexion between salinity and inflow

#### 3. Comparison of fluctuations from year to year in the quarterly means of differences of water-level with fluctuations of salinity and observed current.

As demonstrated by la Cour[12]), a very close connexion exists between the difference of water-level at Gedser—Hornbæk and the surface current at Lappegrunden, and so we can use the difference of waterlevel as a measure of the variations in the strength of current.

As pointed out by Jacobsen*) we might

[12]) D. la Cour: Quasinivellement. — Publikationer fra det danske Meteorologiske Institut. Meddelelser No. 1. København. 1913.

*) J. P. Jacobsen: Unterliegt die Höhendifferenz zweier fester Punkte bei Hornbæk und Gjedser einer jährlischen Variation? — Verhandlungen der siebenten Tagung der Baltischen Geodätischen Kommission. Helsinki 1936.

ct to find an even closer connexion between rence of waterlevel and current if the differ- of waterlevel was compared to the current rogden. It is a fact that the surface current at egrunden is a poor representative of currents gh the Sound because a considerable quantity ater enters the northern part of the Sound the Kattegat in the lower layer and returns e Kattegat in the upper layer. On account of we find at the surface of Lappegrunden a cur- component the variations of which must be tically independent of the variations of the ent at Drogden.

## Table 27.

rterly means of waterlevel-difference Gedser—bæk correlated with contemporary observed ent and salinity, respectively, at Drogden L. V.

| | Ingoing | Outgoing | Resulting | Salinity |
|---|---|---|---|---|
| quarter ..... | 0·64 | 0·10 | 0·46 | —0·48 |
| „ ..... | 0·80 | —0·03 | 0·60 | —0·34 |
| „ ..... | 0·64 | 0·30 | 0·75 | —0·62 |
| „ ..... | 0·71 | 0·14 | 0·68 | —0·56 |

f we reduce the waterlevels of Gedser and bæk to the Danish Normal Nil (DNN) and correlate, for the different quarters, the diffe- e of waterlevel at both localities with the cor- onding differences Ystad—Hornbæk (waterlevel Ystad reduced to SNN)*) we get rather large ficients, e.g. for 2nd quarter $r = 0{\cdot}48$. If for 2nd quarter we correlate observed resulting ent at Drogden with difference Gedser—Horn- and Ystad—Hornbæk we get $r = 0{\cdot}60$ and 0·51, respectively (reckoned for the years 3—1932). Thus the difference Gedser—Horn- seems just as good an expression for the ent as the difference Ystad—Hornbæk. In Table 27, therefore, we have presented the correlation coefficients between the first named difference only, and current and salinity at Drogden, respectively.

*Differences of waterlevel in the water Fehmarn Belt —Great Belt.*

The current from Gedser—Warnemünde to the Great Belt can be measured in several ways by means of the differences of waterlevel. We may here look at the difference in waterlevel between Gedser and Warnemünde, the difference between Korsør and Slipshavn, and at the slope of the waterlevel between Gedser—Warnemünde and Korsør—Slipshavn.

Now it turns out that these expressions give rather different values for the resulting current. The latter must naturally be practically the same in the sections Gedser—Warnemünde and Slipshavn—Korsør, for only a very small difference in the quarterly means of the two localities can arise by some water passing through Storstrømmen and Little Belt or by a change occurring in the quantity of water inside the area between Gedser and Sprogø.

Of course the waterlevel does not depend on the current alone but also on local accumulations of water due to the wind, and such accumulations are supposed to be the cause of the lack of correspondence.

However, it appears from calculations of the correlation between the differences of waterlevel and such values for water discharge, precipitation and change of water quantity as have been calculated by Witting for the years 1898—1912 (cp. Table 30), that the differences Korsør—Slipshavn and Warnemünde or Gedser—Slipshavn seem to show a co-variation with the values found by Witting. If, among these, we choose the differences Korsør—Slipshavn and Gedser—Slipshavn and correlate them with the observed resulting current at Drogden as shown in Table 28, we find a rather distinct co-variation, particularly between this current and the difference Gedser—Slipshavn. Table 28 also shows the coefficients of a correlation of the differences Korsør—Slipshavn and Gedser—

*) Årsbok. Statens meteorologisk-hydrografiska Anstalt. kholm, and Folke Bergsteen: Vattenstånden vid ts Kuster Åren 1887—1921. — Meddelanden från Sta- meterologisk-hydrografiska Anstalt. Bd. 2. No. 4. kholm. 1925.

## Table 28.

ter-level difference between Slipshavn and Korsör, and between Gedser and Slipshavn in the erent quarters of the year correlated with observed resulting current at Drogden, and with salinity at Schultz Grund, Surface and Bottom, respectively.

| | Ko. — Sl. | | | | Ge. — Sl. | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st. | 2nd. | 3rd. | 4th. | 1st. | 2nd. | 3rd. | 4th. |
| rent at Drogden, same quarter ..... | 0·18 | 0·20 | **0·31** | 0·13 | **0·43** | **0·51** | **0·57** | **0·47** |
| nity, surface, quarter, not displaced.. | 0·17 | —0·19 | 0·00 | —0·13 | —0·01 | —0·25 | 0·29 | —0·12 |
| „ „ „ 1 month later . | —0·17 | **—0·24** | —0·45 | **—0·25** | —0·30 | **—0·48** | —0·32 | **—0·44** |
| „ „ „ 2 months later. | **—0·42** | —0·13 | **—0·55** | —0·22 | **—0·40** | —0·29 | **—0·55** | **—0·44** |
| „ „ „ 3 months later. | —0·26 | —0·15 | —0·17 | —0·17 | —0·28 | —0·19 | —0·40 | —0·39 |
| nity, bottom, quarter, not displaced.. | **—0·22** | **—0·38** | **—0·40** | **—0·38** | **—0·27** | **—0·20** | **—0·49** | **—0·54** |
| „ „ „ 1 month later . | —0·21 | —0·16 | —0·20 | —0·19 | —0·24 | —0·07 | —0·24 | —0·21 |
| „ „ „ 2 months later. | —0·17 | —0·16 | —0·11 | —0·03 | —0·12 | 0·03 | 0·06 | 0·08 |

Slipshavn with the surface and bottom salinity at the Schultz Grund; as was the case in our examination of the co-variation with the current at Drogden, we here find the most distinct co-variation if we look at the difference Gedser—Slipshavn. Of the two differences considered this is no doubt the better representative of the resulting current.

When the preponderance of the outgoing current (generally the upper current) over the ingoing (in most cases the lower current) is greater than usual, so that the resulting current of upper plus lower layer shows a comparatively pronounced outflowing trend, we find at the same time a tendency of lower salinities at bottom and a tendency of the next months showing a lower surface-salinity than usual. That the salinity anomaly at surface occurs later than the corresponding anomaly of the current is due to the fact that the surface salinity is greatly influenced by admixture from the lower layer.

### D. Water discharge, precipitation and wind as causes of fluctuations of current and salinity.

The values calculated by Witting[5]) in 1918, p. 228, for water discharge, changes of water quantities and addition of meteoric water to the Baltic in the years 1898—1912, constitute a means of examining the causes of fluctuations of current and salinity. Unfortunately, they include only the short period of 15 years, and consequently the conclusions reached on the basis of a correlation with observed current and salinity are subject to considerable error of probability (cp. section II).

The water discharge, i.e., the quantity of water given off by the Baltic in course of one calendar year, is the sum of the change (decrease) of the water quantity of the Baltic and the quantity of meteoric water added to the Baltic in the same calendar year. The amount of meteoric water is calculated as precipitation ($P$) over the Baltic plus the quantity of water originating from the surrounding terrestrial areas ($R$) minus the amount of water evaporating from the Baltic ($E$). It is characterized in the following as $P + R - E$.

The decrease of water quantity and $P + R$ - seems to be practically independent of each ot the correlation being $r = 0{\cdot}10$ only.

**1.** Fluctuations in current.

If we correlate water discharge, changes water quantity and $P + R - E$ with the obser current at Drogden, we find the coefficients Table 29. As might be expected the observed going current shows a negative correlation with three quantities. The outgoing current, howe shows no ostensible positive correlation v Witting's values. It has already been poir out that the observed outgoing current seems to a poor representative of outgoing current thro the Sound.

We note that the correlation coefficients very small which, to an essential degree, must ascribed to the defectiveness of the current servations in various respects (see above). Stil is no doubt justifiable to attach some importance their variation. It is seen that a decrease of wa quantity is accompanied by a corresponding sim taneous (*and* quickly following) resulting outgoi current, that a change of $P + R - E$ is follow by a corresponding change of the resulting, o going current some 3 months later and that c sequently the water discharge shows a co-variati with the resulting outgoing current during the sa and, particularly, during the immediately followi period. However, the phase difference betwe $P + R - E$ and water discharge on one hand a resulting current on the other is undoubtedly d to the circumstance that the observed outgoing c rent can hardly be considered representative of t true outgoing current.

Finally, attention is called to the fact th water discharge, changes of water quantity, a meteoric water, show a very considerable c variation with most differences of waterlevel in t areas from Gedser—Darss to the Great Belt a through the Sound, as shown in Table 30. Wh allowance is made for the supposition that t differences are often influenced by local accumul

## Table 29.

Values for *water discharge*, *changes of water quantity* and $P + R - E$ (from Witting, 1918) correlate with annual means of observed current at Drogden in the same year and in 12 months periods displace 3, 6 and 9 months, respectively (current from the Baltic reckoned positive); calculated for 15 year

| Observed current in | Water discharge correlated with | | | Changes of water quantity correlated with | | | $P + R - E$ correlated with | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ingoing current | Outgoing current | Resulting current | Ingoing current | Outgoing current | Resulting current | Ingoing current | Outgoing current | Resulti curren |
| same year (Jan.—Dec.) ..... | 0·61 | —0·11 | 0·19 | 0·38 | 0·11 | 0·36 | 0·57 | —0·40 | —0·0 |
| year, 3 months later (Apr.—Mar.) | 0·53 | —0·06 | 0·34 | 0·25 | 0·01 | 0·45 | 0·60 | —0·14 | 0·2 |
| year, 6 months later (July—June) | 0·08 | —0·08 | 0·08 | —0·05 | 0·09 | 0·09 | 0·27 | —0·33 | —0·2 |
| year, 9 months later (Oct.—Sept.) | 0·13 | —0·17 | 0·04 | 0·03 | —0·03 | 0·13 | —0·05 | —0·33 | —0·1 |

## Table 30.

r-discharge, change of water quantity and $R-E$ (from Witting, 1918) correlated with differences of water level (15 years).

| | Water-discharge | Change of water quantity | $P+R-E$ |
|---|---|---|---|
| er—Warnemünde .... | —0·15 | 0·16 | —0·53 |
| ör—Slipshavn ..... | 0·54 | 0·42 | 0·45 |
| er—Korsör ..... | 0·46 | 0·51 | 0·08 |
| er—Slipshavn ..... | 0·69 | 0·69 | 0·24 |
| emünde—Slipshavn . | 0·81 | 0·54 | 0·71 |
| W. — Ko. + Sl. / 2 ..... | 0·77 | 0·64 | —0·04 |
| —Hornbæk ..... | 0·73 | 0·61 | 0·46 |
| er—Hornbæk ..... | 0·27 | 0·50 | —0·26 |

of water, the correspondence is in most cases remarkable.

luctuations in salinity.

n Table 31 water discharge, decrease of water tity and $P + R - E$ are correlated with the ty at surface, and in Table 32 the correspond- alculations are made for the bottom salinity. s might be expected beforehand the co- tion found is as follows.

certain decrease of water quantity shows a ive correlation with the contemporary salinity at bottom and surface. A connexion with the m salinity can be established in the southern gat only. However, the outgoing current ts the simultaneous surface salinity to a rather degree because this salinity is so highly in- ced also by admixture from the lower layer is determined by the salinity of the latter g the previous period. For this reason a mum co-variation between the decrease of quantity and the surface salinity must show tain difference of phase, appearing from the to be about 3 months (which goes well with hase difference found above (tables 10, 11, 3) for the positive co-variation between the ties at bottom and at surface).

n the same way a certain change of $P + R - E$ shortly later bring about a corresponding ge of current. So here, too, we find a negative lation with the salinity at surface and bottom same time and during the immediate future. rrelation with the salinity at bottom gives a mum size of the coefficient when the years by 3 months.

owever, the maximum effect of $P + R - E$ e surface salinity shows a phase difference of months on account of the gradual spreading e water intermixed with the meteoric water. nter, part of it will be ice bound in the inner for a shorter or longer period, and further- the moving of the water from the mouths of ivers to the central part of the Baltic, to the

## Table 31.

Values for *water discharge, changes of water quantity* and $P + R - E$ (from Witting, 1918) correlated with annual means of surface-salinity in the same year, and in 12-month periods displaced 3, 6, 9 and 12 months, respectively (15 years).

| Salinity in | Water discharge corr. with surface-salinity at | | | | Changes of water quantity corr. with surface-salinity at | | | | $P + R - E$ corr. with surface-salinity at | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Christianse | Drogden | Gedser | Schultz Grund | Anholt Knob | Christianse | Drogden | Gedser | Schultz Grund | Anholt Knob | Christianse | Drogden | Gedser | Schultz Grund | Anholt Knob |
| same year (Jan.—Dec.) .... | —0·28 | —0·30 | —0·45 | —0·46 | —0·21 | —0·26 | —0·50 | —0·37 | —0·46 | —0·29 | —0·12 | 0·21 | —0·39 | —0·31 | —0·16 |
| year, 3 months later (Apr.—Mar.) ... | —0·22 | **—0·72** | **—0·75** | **—0·66** | **—0·41** | **—0·40** | **—0·80** | **—0·69** | **—0·66** | **—0·57** | —0·26 | —0·18 | —0·46 | —0·34 | —0·09 |
| year, 6 months later (July—June) ... | **—0·44** | —0·43 | —0·65 | —0·28 | —0·24 | —0·36 | —0·48 | —0·50 | —0·02 | —0·15 | —0·37 | —0·14 | —0·52 | —0·29 | —0·12 |
| year, 9 months later (Oct.—Sep.) .... | —0·42 | —0·31 | —0·61 | —0·04 | —0·01 | —0·27 | —0·19 | —0·36 | 0·18 | 0·13 | **—0·39** | **—0·23** | **—0·61** | **—0·40** | **—0·40** |
| following year (Jan.—Dec.) .... | —0·07 | —0·07 | —0·22 | 0·29 | 0·12 | —0·02 | 0·08 | —0·22 | 0·20 | 0·22 | —0·17 | 0·06 | —0·16 | 0·18 | —0·13 |

## Table 32.

Values for *water discharge, changes of water quantity* and $P + R - E$ (from Witting, 1918) correla with annual means of bottom-salinity in the same year, and in 12-month periods displaced 3 and months, respectively (15 years).

| | Water discharge corr. with salinity at | | | Changes of water quantity corr. with salinity at | | | $P + R - E$ corr. with salinity at | | |
|---|---|---|---|---|---|---|---|---|---|
| | Schultz Grund | Anholt Knob | Skagens Rev | Schultz Grund | Anholt Knob | Skagens Rev | Schultz Grund | Anholt Knob | Ska R |
| same year (Jan.—Dec.) ..... | —0·73 | —0·50 | —0·16 | —0·63 | —0·26 | 0·20 | —0·40 | —0·36 | —0 |
| year, 3 months later (Apr.—Mar.) | —0·49 | —0·13 | —0·09 | —0·37 | —0·03 | 0·09 | —0·59 | —0·15 | —0 |
| year, 6 months later (July—June) | —0·04 | —0·01 | —0·33 | 0·05 | 0·17 | —0·23 | —0·39 | —0·10 | —0 |

Sound, the Belt Sea and the Kattegat takes some time. The phase is of course found to be shortest at Christiansø, a little longer at Drogden and Gedser, and longest in the Kattegat*).

Unfortunately, Witting's calculations of the variations of meteoric water ($P + R - E$) cover a period of 15 years only. As will appear from the present calculations of the co-variation between Witting's values and salinity (and current) the variations of the meteoric water undoubtedly play a very considerable part. Indeed, this has been pointed out long ago by R. Ruppin (1912, p. 227). A continuation throughout a longer period of years of Witting's calculation of $P + R - E$ would be of very great value, but was impossible in the present case. For the purpose of getting a survey of the variations, more particularly for a contemplation of the secular changes, a few comparisons have been made between the precipitation and the flow of water in the rivers, and the variations have been plotted on Figure 7.

The particularly low values of the precipitation in the years 1908, 1914, 1920 and 1933 were followed by low values of the surface salinity in the following years; among the years showing particularly high values of precipitation 1910, 1912, and 1916 only were followed by high surface salinities in the Kattegat whereas others, e.g., 1903, 1927 and 1931, did not show any consequent rise in surface salinity.

The pressure gradient. From Jacobsen's investigations (1913, p. 14)[4]) on the effect of winds from different quarters on the surface current it appeared that winds from the S.W., W., N.W., and N. will generally induce an ingoing current at the lightvessels inside the Skaw whereas winds from the N.E., E., S.E., and S. will tend to give outgoing currents, pronounced differences, however, occurring from one lightvessel to another and in course of the year. The pressure gradient

*)In other words the length of the phase corresponds to the facts that the annual maximum of precipitation occurs in the autumn, the annual minimum salinity of that part of the Transition Area considered here appearing about May or June, and that the annual minimum of precipitation is recorded in May, the annual salinity maximum in December.

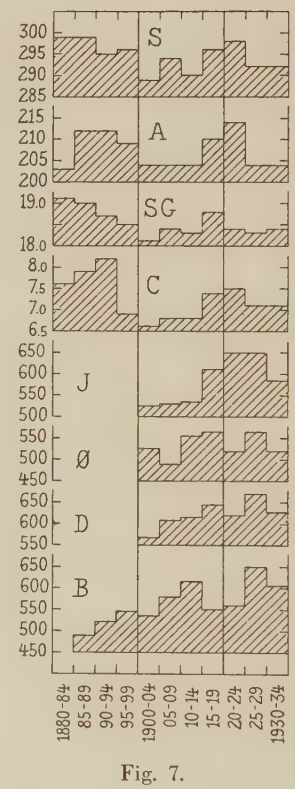


Fig. 7.

5-year means of surface salinity at Skagens Rev (S), Anholt Knob (A), and Schultz Grund (S. G.), light vessels and at Christiansø (C), compared with precipitation at Bornholm (B), Germany (D), mean of Tilsit, Osterode, Stettin, and Breslau), and Östergötland (Ø) and Jämtland (J) in Sweden.

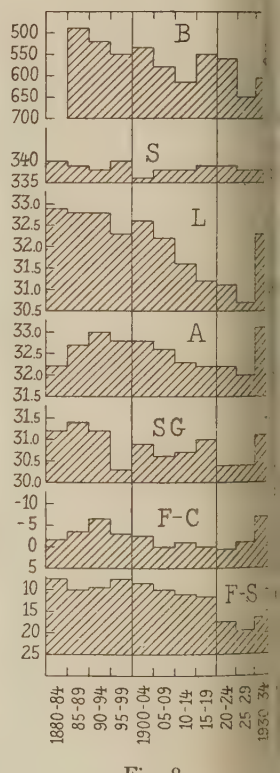


Fig. 8.

5-year means of botto salinity at Skagens Rev, 3 m. (S), Læsø Rende, 21 n (L), Anholt Knob, 28 n (A), and Schultz Grund, 2 m. (S. G.), light vessel compared with difference i barometric pressure Fanø-Copenhagen (F—C) an Fanø—Skaw (F—S), re spectively.

## Table 33.

terly means of difference in barometric pressure correlated with surface salinity in the same quarter in quarters displaced one or more months, respectively (calculated for the years 1898—1926).

| | Fanø—Skaw | | | | Copenhagen—Skaw | | | | Fanø—Copenhagen | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quarter: | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th |
| olt Knob, linity in | | | | | | | | | | | | |
| quarter ... | **0·58** | **0·59** | **0·66** | **0·65** | **0·59** | **0·51** | **0·63** | **0·49** | **0·45** | **0·37** | 0·11 | **0·48** |
| nth later ... | 0·13 | **0·41** | **0·49** | **0·36** | 0·22 | **0·39** | **0·49** | —0·05 | 0·12 | 0·20 | —0·03 | **0·38** |
| ltz Grund, linity in | | | | | | | | | | | | |
| quarter ... | **0·40** | **0·50** | **0·83** | **0·97** | **0·48** | **0·43** | **0·78** | **0·53** | **0·36** | 0·31 | 0·19 | **0·53** |
| nth later ... | —0·12 | 0·33 | **0·46** | 0·19 | —0·04 | **0·36** | **0·35** | 0·12 | 0·01 | 0·10 | —0·07 | 0·17 |
| nths later .. | *—0·54* | 0·29 | —0·04 | —0·33 | *—0·41* | 0·24 | 0·05 | —0·22 | —0·18 | 0·19 | —0·18 | —0·22 |
| nths later .. | *—0·48* | 0·10 | *—0·38* | *—0·50* | *—0·54* | 0·04 | *—0·37* | —0·17 | —0·27 | 0·13 | —0·09 | *—0·50* |
| nths later .. | —0·34 | 0·11 | —0·24 | *—0·46* | *—0·41* | —0·01 | *—0·38* | —0·15 | —0·09 | 0·23 | 0·10 | *—0·50* |

## Table 34.

terly means of difference in barometric pressure correlated with bottom-salinity in the same quarter in quarters displaced one or more months, respectively (calculated for the years 1898—1926).

| | Fanø—Skaw | | | | Copenhagen—Skaw | | | | Fanø—Copenhagen | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quarter: | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th |
| ens Rev, linity in | | | | | | | | | | | | |
| quarter ... | 0·11 | —0·20 | *—0·41* | 0·18 | —0·08 | *—0·35* | *—0·48* | 0·14 | —0·11 | 0·11 | —0·07 | 0·16 |
| nth later ... | —0·05 | —0·32 | —0·28 | 0·19 | —0·27 | *—0·44* | —0·27 | 0·30 | 0·10 | 0·03 | —0·07 | 0·01 |
| nths later .. | 0·02 | —0·11 | 0·01 | 0·12 | —0·24 | —0·15 | 0·13 | 0·32 | 0·12 | 0·01 | —0·09 | —0·11 |
| olt Knob, linity in | | | | | | | | | | | | |
| quarter ... | *—0·55* | *—0·35* | *—0·52* | *—0·50* | *—0·58* | *—0·35* | *—0·60* | *—0·53* | —0·16 | —0·01 | —0·07 | —0·16 |
| nth later ... | *—0·52* | *—0·53* | *—0·51* | *—0·56* | *—0·67* | *—0 65* | *—0 46* | *—0·53* | —0·12 | —0·05 | —0·07 | —0·27 |
| nths later .. | —0·29 | *—0·54* | *—0·40* | *—0·37* | *—0·46* | *—0·58* | *—0·41* | —0·27 | 0·06 | —0·20 | —0·10 | —0·27 |
| nths later .. | —0·06 | —0·28 | —0·03 | —0·21 | —0·22 | —0·29 | —0·11 | —0·06 | 0·22 | —0·10 | —0·10 | —0·22 |
| ltz Grund, linity in | | | | | | | | | | | | |
| month .... | *—0·57* | —0·06 | *—0·42* | *—0·40* | *—0·45* | 0·13 | *—0·46* | —0·32 | *—0·53* | —0·30 | 0·04 | —0·10 |
| nth later ... | *—0·49* | *—0·40* | *—0·62* | *—0·69* | *—0·44* | —0·22 | *—0·63* | *—0·50* | *—0·46* | *—0·42* | —0·10 | *—0·52* |
| nths later .. | *—0·41* | *—0·43* | *—0·50* | *—0·53* | *—0·53* | —0·28 | *—0·60* | *—0·40* | —0·16 | *—0·41* | 0·18 | *—0·48* |
| nths later .. | *—0·37* | —0·14 | —0·31 | —0·23 | *—0·55* | —0·03 | —0·32 | —0·19 | —0·11 | —0·22 | 0·06 | —0·24 |

to a considerable degree, be taken as a ure of the wind blowing at right angles to the tion of the gradient. In the following the tions of salinity and observed current are fore compared partly to the pressure gradient - Skaw, the direction of which corresponds y well to the limit between such directions of s give the in- and outgoing currents, respec- y. partly to the pressure gradients Copenhagen aw, which is all but square to the average tion of the isobars, and Fanø—Copenhagen, h is nearly parallel to this direction. The sure gradient Fanø—Copenhagen is measured he direction from W. × S. to E. × N. and equently expresses the wind component in the tion from N. × W. and is measured positive his direction. The pressure gradient Copenhagen—Skaw expresses the wind component from W. S. W., measured positive in this direction. The pressure gradient Fanø—Skaw expresses the wind component in the direction from W.N.W., measured positive in this direction. From 1927 inclusive, no observations of pressure were made at the Skaw, and instead of the gradient Copenhagen—Skaw I have therefore used the pressure gradient calculated from the difference of pressure between Fanø and Tylstrup, the latter being situated near to the line Fanø—Skaw, and the distance from Fanø to Tylstrup and the Skaw, respectively, being approximately = 3:4.

In Table 33 these pressure gradients have been correlated with the surface salinities at the light vessels Anholt Knob and Schultz Grund.

In Table 34 the gradients have been correlated

with the bottom salinities at the Skagens Rev, Læsø Rende, Anholt Knob and Schultz Grund L.V.

Also here we observe that the wind influences the salinity to a very considerable degree and *that the wind causing an ingoing current at the surface (westerly and north-westerly component) gives a rising salinity at surface and a low salinity at bottom in the same and the following months. This salinity at bottom reacts on the surface salinity 2 or 3 months later and gives a negative correlation between the pressure gradient causing the ingoing current and the surface salinity 2 or 3 months later.*

When we consider a longer period, e. g., a year or more, we cannot expect to find a very close connexion between wind and surface salinity on account of this double effect. It is true that a strong western wind will at first increase the salinity at the surface because it hinders the outflow, but at the same time it will bring about a slackening of the inflow in the lower layer and, consequently, a reduction of the admixture of lower layer water to the upper layer during the time immediately following, so that less salt than usual is added to the surface layers. Further, it is well-known that the western wind shows a positive, although for a longer period as, e. g., a year rather inconsiderable, correlation with the precipitation, another fact counteracting the direct effect of the wind on the surface salinity. If the annual mean salinity of the surface water at the Schultz Grund (for the years 1898—1934) is correlated with the annual mean of the pressure gradients we therefore in all cases get positive, but very inconsiderable correlation-coefficients — as might be expected (see Table 35).

**Table 35.**

Average for the year of difference of barometric pressure correlated with salinity (calculated for the years 1898—1934).

| Salinity at | Difference of barometric pressure | | |
|---|---|---|---|
| | Fanø—Skaw | Copenhagen—Skaw | Fanø—Copenhagen |
| Schultz Grund, Surf .... | 0·21 | 0·12 | 0·22 |
| Christiansø, Surf. ..... | 0·28 | 0·35 | 0·10 |
| Schultz Grund, Bottom .. | —0·37 | —0·24 | —0·37 |
| Anholt Knob, Bottom ... | —0·17 | —0·01 | —0·54 |
| Skagens Rev, Bottom ... | 0·39 | 0·41 | 0·13 |

If on the other hand we compare the annual mean salinity of the bottom water with the pressure gradients, we find distinct negative correlations at all lightvessels except the Skaw (calculated for the years 1898—1934).

*The effect of the western wind on the bottom salinity in the central and southern Kattegat is an indirect one: it delays the outflow in the upp layer and consequently the inflow in the lower on*

The annual mean salinity at the Skaw, Botto follows the variations of the pressure gradie rather closely, but in contrast to the other ligh vessels the correlation is here a positive one. N doubt the explanation of this fact is that *a stro western wind will force the water from the Nor Sea towards the Skagerak and thus try to increa the salinity of the bottom water at the Skaw a that this effect here outweighs the indirect effect the western wind.* A look at the correlation coeff cients between the pressure gradients and t bottom salinity at the Skaw for the individu quarters will show that here, too, the indirect effe of the wind seems to preponderate during t quarters showing the sharpest distinction betwee upper and lower layer, i. e., the second and thi quarter (see Table 34).

*On account of the fact that the effect of th wind on the annual mean salinity at the Skaw Bottom, is contrary to that found at the Schult Grund we find a partially reversed course of th secular changes of the two localities.* If values o the bottom salinity at the Skaw, smoothed pe 3 years, are correlated with corresponding value for the Schultz Grund, we get the coefficien $r = -0{\cdot}444$. Between values of salinity, smoothe per 3 years, in the bottom and surface water a the Skaw there is a correlation coefficient o $r = 0{\cdot}651$ principally because, at the Skaw, th fluctuations in the annual mean of bottom as wel as surface water are due to the direct effect o the wind.

For the years 1909—34 I have further cal culated the current at Drogden from the wind b the formula found by Jacobsen, 1913, p. 14[4]) (in the same manner as done by Jacobsen i the named paper). Correlated with the salinity o various localities the annual values found in thi way give the following coefficients (for the year 1904—34).

Jacobsen's wind-current correlated with

salinity at Drogden, Surface: $r = -0{\cdot}42$;
salinity at the Anholt Knob — Schultz Grund, 0 m.: $r = -0{\cdot}44$;
salinity at the Anholt Knob — Schultz Grund, Bottom: $r = +0{\cdot}56$;
salinity at the Skaw, Bottom: $r = -0{\cdot}12$.

A correlation of the annual mean salinity a the Skaw, Bottom, with the annual mean salinity in the southern Kattegat, surface, (mean of the Schultz Grund and Anholt Knob) gives the coefficient $r = 0{\cdot}486$. The connexion seems to be independent of the influence of the wind, for we get the same coefficient, $r = 0{\cdot}485$, if the correlation is calculated between the bottom salinity at the Skaw and a surface salinity reduced for the

ct of the wind (or rather: the pressure gra-
ts added after calculation of regression
fficients), and so the connexion must be due
fly to the fact that a salt anomaly from the
om of the Skaw spreads through the lower
r of the Kattegat to its upper layer during the
owing months.

Since 1929 the salinity in the lower layer of the
thern and Middle Kattegat has been consider-
above normal and simultaneous with an in-
sed southern component of the wind. It is of
ial interest that it can be stated that the lower
ent in these years has been very much stronger
before 1929 (cp. chapter V. A. 2 and Fig. 8).

**Causes of fluctuations in the temperature of the water.**

We have seen above (section IV A) that fluc-
ions of the temperature are to some degree due
e moving and intermixing of the water bodies.
ever, the principal cause of the variations in
temperature of the surface is the variation of
temperature of the atmosphere, and also the
erature of the lower layer is greatly influenced
his factor.

A calculation of the correlation between the
erature of the atmosphere at Copenhagen and
surface temperature of the Kattegat in the same
s the coefficients of Table 36.

## Table 36.

perature of the surface-water in Kattegat corre-
d with air temperature at Copenhagen (Landbo-
højskolen).

| | r | | r |
|---|---|---|---|
| ..... | 0·78 | July ..... | 0·89 |
| ..... | 0·86 | Aug. ..... | 0·88 |
| ..... | 0·79 | Sep. ..... | 0·80 |
| ..... | 0·81 | Oct. ..... | 0·90 |
| ..... | 0·71 | Nov. ..... | 0·75 |
| ..... | 0·85 | Dec. ..... | 0·74 |

The outspoken correlation between the tempera-
s of atmosphere and water in the same month
principally due to the simultaneous effect of
insolation on the atmosphere and the water
to their interchange of heat.

The rather small independent effect of the
r on the temperature of the atmosphere during
early summer months was demonstrated by
C. Johansen and Aage J. C. Jensen[10]).
orresponding effect can be established in the
mn.

There is a considerable correlation, also, be-
n the temperature of the atmosphere in one
th, and the surface temperature of the water
he following months, of course due to the stability of the temperature of the atmosphere (see Table 20) and, to a still higher degree, of that of the water (see Table 19),

*The influence of the winter-temperature of the air is also very appreciable in the lower layer* (see Table 37); *as might be expected the effect occurs*

## Table 37.

Air temperature at Copenhagen (Landbohøjskolen) in winter (D. J. F. M.) and summer (J. J. A.), respectively, correlated with the temperature of the bottom water in different 3-month periods.

| Air temperature, winter, corr. with | | | Air temp., summer, corr. with | |
|---|---|---|---|---|
| Temp. at: in | Skagens Rev | Schultz Grund | Temp. at: in | Schultz Grund |
| J. F. M. | **0·52** | 0·00 | J. J. A. | —0·29 |
| F. M. A. | **0·77** | 0·18 | J. A. S. | *—0·35* |
| M. A. M. | **0·84** | 0·26 | A. S. O. | 0·04 |
| A. M. J. | **0·78** | **0·37** | S. O. N. | 0·13 |
| M. J. J. | **0·53** | **0·44** | O. N. D. | —0·09 |
| J. J. A. | 0·15 | **0·41** | N. D. J. | —0·09 |

*after some delay*. In winter the phase difference is about 2 months at the Skaw, about 4 months at the Schultz Grund. *During the summer negative correlations are found between air temperature and bottom temperature at Schultz Grund in the same and the following months, respectively*. This is a consequence of the fact that a high temperature diminishes the specific gravity of the surface water, thus causing less mixing with the lower layer; it is in accordance, also, to what is found above as to the water-movements. Between the contemporary salinity and temperature there is, in summer, a negative correlation partially on account of the influence of the temperature on the mixing (cp. Tables 16 and 17). Thus — to take an example — a high temperature at the surface corresponds to a contemporary low salinity at the surface, and to a high salinity at bottom in the following months (Tables 10, 11, 12 and 13), and this corresponds to a contemporary low temperature at bottom. Comparing the air temperature in summer with temperature at bottom two months later we cannot perceive any co-variation. This undoubtedly is due to the fact that there will be a tendency also to a positive correlation between the temperature of the air and the temperature at bottom some months later. The air-temperature naturally is positively correlated with the temperature of the water mass of the North Sea and the Southern Skagerak which during the following months form the water of the lower layer in the Kattegat.

As was the case with the influence of the between the maximum effects at the Skaw and at surface salinity on the lower layer the difference the Schultz Grund is here noted to be largest in

winter, the season at which the spreading of anomalies through the lower layer from the Skaw to the Schultz Grund takes place at the slowest rate. In contrast to the salinity, however, the maximum effect of the temperature of the air on the bottom water at the Skaw shows a considerable phase difference of about 1 or 2 months. This phase difference must be ascribed to the fact that *the temperature of the bottom water at the Skaw was determined during the previous months when this water was moving from the North Sea through the Skagerak.*

The connexion of the variations in the temperature of the atmosphere with the temperature at the Schultz Grund, Bottom, is far less outspoken than is the connexion with the temperature at the Skagens Rev, Bottom. Of course such variations as depend on changes in the temperature of the air must be obliterated on their way from the Skaw through the Kattegat to the Schultz Grund, i. a., because they are influenced by the size of the water transport. It appeared from the investigations in section IV, A that the water transport depends principally on the pressure gradient, so that strong westerly winds mean an inconsiderable inflow (and low salinity) at the bottom. If we correlate the pressure gradient with the temperature at the Schultz Grund, Bottom, in the same and the following months we get therefore a maximum of correlation with the same phase difference as was found in our examination of the connexion between pressure gradient and salinity, and of course in such a way that in winter we find a negative correlation between a pressure gradient causing a reduction of outflow in the upper layer and the corresponding temperature in the lower layer. A reduced outflow in the upper layer is followed by a decreasing inflow in the lower layer during the following months and, consequently, we also observe a drop in temperature in the lower layer in winter, and *vice versa.*

It is well-known that the temperature of the atmosphere in winter rises with the predominance of western winds, and on this ground, also, there is a positive correlation between the pressure gradient occurring simultaneous with the winter temperature and the temperature of the bottom water at the Schultz Grund 3 or 4 months later.

The annual variation in the temperature of the bottom water is highly influenced by the difference of the rate of inflow in winter and summer. We have seen above that the time required for an inflow of water from the Skagerak to the Schultz Grund may be put at 4 months in winter and 2 months in summer; this means that the winter temperature of the atmosphere will influence the bottom water of the southern Kattegat in the months of early summer. In early summer the rate of inflow is rising and so the temperature of the bottom water at the Schultz Grund in summer is determined by the temperature of the air partly i spring, partly in early summer. Consequently, t water temperature at the Schultz Grund, Bottom, lower than at the Skaw, Bottom, from April September, in June, July and August by about 2°

In autumn and winter when the rate of inflo in the lower layer decreases, the temperature of t bottom water during several months is direct influenced by the temperature of the atmosphe during a short period in late summer and autum Moreover there is a tendency to a negative co relation between air temperature and bottom ter perature (see above). Therefore the temperatur of the bottom water at Schultz Grund in autur and winter become little or no higher than at t Skaw.

The annual variation in rate of inflow in t northern Kattegat and the Kattegat as a whole different from that of the southern Kattegat, and i accordance with the fact that the inflow of t locality first mentioned — the area between th Skaw and the Anholt Knob — reaches its maximu in the second and third quarter, the summe temperature at the Anholt Knob, Bottom, depend on the summer temperature of the Skaw, Botton to a higher degree than does the summer tempera ture at the Schultz Grund, Bottom; consequently the summer temperature of the bottom water i about the same at the Skaw and at the Anhol Knob, but considerably lower at the Schultz Grund

## V. Secular Changes in the Hydrograph of the Transition Area during the pas 50 Years.

The direct observations of current cannot b used for an examination of the changes that hav taken place in respect of currents because, as de monstrated in section IV, C, 1, they are subjec to systematic errors, which may have altered i the progress of time.

The differences of waterlevel suffer fron another drawback: their changes in the course o years are undoubtedly considerably influenced by upheavals or sinking of the crust of the earth.

W i t t i n g[5]) has demonstrated that an upheava of the north-eastern part of the Transition Area ha taken place between 1898 and 1912, amounting to about 1 mm. a year along the line Skaw—Born holm whereas the line Gedser—Nyborg—Aalborg i nearly unchanged.

By comparing the changes of waterlevel at various localities of Denmark E g e d a l*) has shown that a corresponding change of waterlevel has occurred during the period 1885—1925. Part of these variations of waterlevel in the Belt Sea

*) J. E g e d a l: On the Determination of the Normal Height of the Sea-level Round the Danish Coasts. Publikationer fra det Danske Meteorologiske Institut. Aarbøger. København 1933.

y be due to such changes of both local accumu-ons and strength of current resulting from the stantly increasing predominance of westerly ds. A calculation of the correlation between the ual mean-differences of waterlevel Korsør—shavn and Gedser—Slipshavn, respectively, and differences of pressure gives the following fficients (recorded for the years 1898—1926):

| Difference of waterlevel | Difference of pressure Copenhagen—Skaw | Fanø—Skaw | Fanø—Copenhagen |
|---|---|---|---|
| sør—Slipshavn .. | —0·12 | —0·35 | —0·15 |
| ser—Slipshavn .. | 0·19 | 0·04 | 0·02 |

The fact that all the correlation-coefficients be-en pressure-difference and difference of water-l Korsør—Slipshavn are negative directly shows the fluctuations from year to year of the ual mean of this waterlevel-difference is not rmined by an accumulative effect of the wind. his was the case a strengthening of the wind ld increase the difference. The signs of the fficients correspond to the fact that a strong ern wind will force the water into the Baltic t an annual mean to a small degree only.

onsidering the coefficients above it should be embered that the pressure difference may be sidered linearly proportional to the force of d, as also the latter is proportional to the are root of the force of the wind-current while difference of waterlevel is linearly proportional he strength of current.

The main cause of the secular change in water-level still must be ascribed to the upheavals (and sinking) of the earth's crust during the series of years considered, and we cannot, therefore, on the basis of secular changes of the differences of water-level, draw any conclusions as to secular changes of the resulting current.

### A. Secular changes of salinity, wind, and precipitation.

An examination of the secular changes of salinity is of interest simply because changes of salinity alone and in connexion with the consequent changes of specific weight, osmotic pressure, etc., are of biologic importance. It is of further interest because the changes, as we have seen above, are highly expressive of the variations of currents. In connexion with the examination of the secular changes of salinity we will look at secular changes of the factors wind and precipitation in their character of producers of current.

**1.** Surface-salinity.

a. *Annual means and 5-year means.*

It appears from the graphical representation of the 5-year means of salinity of the various localities (Figure 7) that, on the whole, the surface salinities in the Baltic, at Christiansø, and in Kattegat have shown the same secular variations *with high values between 1880 and 1894, low values between 1895 and 1914, high ones between 1915 and 1924, and low ones between 1925 and 1935.*

## Table 38.

quency of the various annual means of surface salinity at Christiansø in different periods, and surface salinity in Kattegat in the same periods.

| istiansø<br>ual mean ‰ | 1880—1886 | 1889—1892 | 1897—1913 | 1914—1925 | 1926—1934 |
|---|---|---|---|---|---|
| —6·5 | | | 2 | | |
| —6·7 | | | 2 | | |
| —6·9 | | | 7 | | 3 |
| —7·1 | | | 4 | | 3 |
| —7·3 | | | 2 | 3 | 3 |
| —7·5 | 2 | | | 6 | |
| —7·7 | 4 | | | 1 | |
| —7·9 | 1 | | | 1 | |
| —8·1 | | 2 | | | |
| —8·3 | | 1 | | | |
| —8·5 | | 1 | | | |
| n ‰ | 7·6 | 8·2 | 6·8 | 7·4 | 7·1 |
| ber of years | 7 | 4 | 17 | 12 | 9 |

| tegat | 1880—1892 | 1893—1913 | 1914—1925 | 1926—1934 |
|---|---|---|---|---|
| gens Rev, annual mean ‰ | 29·9 | 29·3 | 29·6 | 29·2 |
| „ „ min.—max. of annual mean ‰ | 28·1 — 31·1 | 28·2 — 30·2 | 28·8 — 31·9 | 27·7 — 30·5 |
| ultz Grund—Anholt Knob, annual mean ‰ | 19·9 | 19·5 | 19·8 | 19·3 |
| „ „ „ „ min. — max. of annual mean ‰ | 18·8 — 21·2 | 18·6 — 20·4 | 18·2 — 21·2 | 18·4 — 20·2 |

**Table 39.**

5-year means of surface salinity (tenths of $^0/_{00}$) at Skagens Rev and Schultz Grund for each quar and for the year.

| | Skagens Rev | | | | | Schultz Grund | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | year | 1st | 2nd | 3rd | 4th | |
| 1880—84 ..... | 310 | 288 | 290 | 306 | 299 | 214 | 171 | 169 | 208 | |
| 1885—89 ..... | 303 | 285 | 305 | 301 | 299 | 199 | 172 | 186 | 203 | |
| 1890—94 ..... | 306 | 278 | 300 | 298 | 295 | 200 | 160 | 185 | 203 | |
| 1895—99 ..... | 304 | 284 | 298 | 306 | 296 | 202 | 159 | 177 | 202 | |
| 1900—04 ..... | 291 | 275 | 292 | 297 | 289 | 187 | 168 | 175 | 194 | |
| 1905—09 ..... | 310 | 276 | 294 | 294 | 294 | 207 | 159 | 179 | 191 | |
| 1910—14 ..... | 304 | 277 | 279 | 301 | 290 | 202 | 157 | 164 | 208 | |
| 1915—19 ..... | 291 | 288 | 303 | 300 | 296 | 192 | 175 | 186 | 200 | |
| 1920—24 ..... | 304 | 283 | 303 | 302 | 298 | 204 | 172 | 184 | 198 | |
| 1925—29 ..... | 296 | 283 | 292 | 299 | 292 | 187 | 171 | 175 | 197 | |
| 1930—34 ..... | 298 | 278 | 295 | 294 | 292 | 198 | 162 | 182 | 196 | |

At Christiansø the secular variations of the last 50 years have been very pronounced. The frequency of occurrence of the various salinities here has been compiled in Table 38. The differences between the periods are so great that erroneous observations as cause are out of question.

In the surface salinity of the Kattegat (the mean of the Schultz Grund, Anholt Knob and Skaw) we find the same variation although much less pronounced (cp. Table 38).

b. *Quarterly and monthly means.*

At Bornholm the variation of the individual quarters is much the same as the annual variation, and the latter is even reflected in the monthly means between September and May whereas the variations of June—August show an irregular run; this is no doubt principally due to the effect of the local precipitation, which at this season differs very much from one locality to another, often taking the form of violent local showers. To some degree the irregularity is also caused by the fact that the surface water shows the highest temperature during these months, thus allowing an easier moving by the wind.

In the Kattegat, however, there is a very great difference between the individual quarters (cp. Fig. 12, and Tables 39 and 48) as well as the individual months. As demonstrated by Table 18, the stability of the salinity is particularly small in autumn and winter.

c. *Causes of secular variations in the salinity of the surface water.*

It appears from an examination of the correlation between the annual mean salinity and the differences of pressure (Table 35) that the surface salinity at Christiansø shows a correlation (although a rather inconsiderable one) with the pressure difference Copenhagen—Skaw, i.e., with the east-western wind component, to the effect that a western wind causes an increase of salinity. The influence of the wind on the annual mean salin of the Kattegat seems to be smaller even. C sequently, we cannot expect to find any disti connexion between the secular variations of p sure and the 5-year mean of salinity. The secu changes of salinity must be due chiefly to variations of precipitation. Unfortunately, a very incomplete combination, only, of the variati of precipitation could be given in this place. T variations of some different localities within precipitation area of the Baltic are shown Figure 7. It seems, however, that the precipitat as a whole has been considerably smaller in Baltic Area before than after the year 1900. some areas we find the opposite change, e.g.. Southern Sweden, where for Götaland H a m b e states that the precipitation was over mean c. 1 —1900 and below mean 1900—1908*).

In the present century the variations precipitation have been very different in southern and northern part of the Baltic countri In central Sweden and in Germany there seems be no substantial changes since the beginning this century. At Bornholm particularly low valu were found in the quinquennial periods 1915— and 1920—24. In Jämtland in North Sweden figures have been high since 1915.

In the salinity at Christiansø we find appr imately the same variations as in the precipitati at Bornholm.

In the surface salinity of the northern Baltic the Åland islands we do not find the same variati as at Christiansø. The Finnish observations for stance, which date as far back as 1905, do show any rise of salinity during 1914. At Märl the mean salinity has been as follows:

*) H. E. H a m b e r g: Nederbörden i Sverige 1860—1 (Les pluies en Suède 1860—1910). Bihang till Meteo logiska Iagttagelser i Sverige. Vol. 52, 1910, Uppsala 19 p. 22. A graph of this variation has been given O. P e t t e r s s o n in: On the occurrence of lunar peri etc. — Ur svenska hydrogr.-biol. Kommissionens Skrift Göteborg 1912.

## Table 40.

ar means of differences in barometric pressure (hundreds of mm.) for each quarter and for the year.

| | Fanø—Copenhagen | | | | | Fanø—Skagen | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | year | 1st | 2nd | 3rd | 4th | year |
| —79 ..... | 45 | 1 | 0 | —36 | 2 | 73 | 56 | 116 | —19 | 57 |
| —84 ..... | —09 | 0 | —26 | —31 | —17 | 120 | —33 | 71 | 81 | 76 |
| —89 ..... | —51 | —18 | —4 | —78 | —38 | 87 | 56 | 164 | 103 | 102 |
| —94 ..... | —49 | —36 | —68 | —104 | —64 | 124 | 40 | 140 | 75 | 95 |
| —99 ..... | —16 | —18 | —15 | —80 | —32 | 77 | 36 | 115 | 100 | 75 |
| —04 ..... | —47 | 2 | 3 | —43 | —23 | 73 | 67 | 121 | 77 | 85 |
| —09 ..... | 15 | 10 | 50 | —70 | 1 | 102 | 66 | 167 | 56 | 99 |
| —14 ..... | —51 | 19 | 48 | —57 | —10 | 124 | 97 | 113 | 92 | 107 |
| —19 ..... | —24 | 13 | 45 | —34 | 0 | 60 | 97 | 196 | 95 | 112 |
| —24 ..... | —3 | 27 | 11 | —25 | 3 | 169 | 177 | 191 | 155 | 172 |
| —29 ..... | —53 | 21 | 7 | —13 | —9 | 146 | 185 | 241 | 203 | 194 |
| —34 ..... | —76 | —67 | —43 | —91 | —69 | 199 | 107 | 187 | 168 | 165 |

| | 1905—1913(-14) | 1920(-19)—1925 | 1926—1933(-34) |
|---|---|---|---|
| uarter ..... | 5·6 | 5·8 | 5·6 |
| „ ..... | 5·5 | 5·5 | 5·5 |
| „ ..... | 5·8 | 5·3 | 5·2 |
| „ ..... | 5·5 | 5·6 | 5·5 |

practically unaltered values throughout the od. The same holds good at other Finnish ons, several of which, however, cannot be ied for this examination because, in more or scattered cases, their salinity is influenced tly by land water. In this part of the Baltic, rently, the great precipitation of the northern ns since 1915 counteract the low precipitation e southern Baltic in these years.

n the whole the precipitation has been rising g these 50 years. In spite of this the surface ity has shown a weak tendency only of sinking s: this must be ascribed to the fact that the ominance of westerly winds during the eighties nineties was less than in the present century has been rapidly rising during this (cp. Figs. H 14, and Table 40). As will appear from the e investigation (Table 33) the quarterly (and hly) means of surface-salinity in the Kattegat nfluenced to a very considerable degree by the mporary difference of pressure, and so the acter of the changes is the same here (cp. Figs. nd 14). In the first quarter there is no characteristic run of the changes in the sur- salinity and in the pressure-difference, but in ourse of 3 to 10 years the quarterly means have varying between high and low values. In the d quarter there is a pronounced rise of the rly (and northerly) wind component from t the beginning of the century till well into the ies, and a corresponding rise of salinity. In hird quarter low values of salinity are re- d until about 1885, high values from about till about 1895, low from about 1895 till about high till about 1925, low ones untill 1927 and that high ones. The corresponding variations are found in the westerly and northerly component of the pressure difference. In the fourth quarter particularly low values were found at the beginning of the century; after that the salinity rose until 1913, the following time showing fairly constant figures. Here, too, corresponding low values of the westerly component of the wind were found about 1900; the constant salinity of the years since 1913 may be ascribed essentially to the fact that the increasing westerly winds and the increasing precipitation have counteracted each other.

*Periods.* In the strength of the wind maxima have occurred about 1890 and about 1925, possibly following a Brückner's period. The same length of period to some degree seems to be found also in the changes of the resulting direction of the wind. Moreover there seems to have been a tendency to a rise in the force of the wind during the half century considered, possibly corresponding to the rise in the temperature of the air.

No doubt the secular changes in the surface salinity is determined essentially by those in the wind and in the precipitation. Also in the precipitation a Brückner's period may be found where humid periods occurred about 1895 and about 1930. A resulting Brückner's period in the surface salinity therefore should have a phase between those of wind and precipitation and this seems to be the case, maxima in salinity occurring about 1890 and 1920, respectively.

The periods of 9—10 and about 18 years referred to below under discussion of the variations in temperature do not seem to be found in the surface salinity. On the other hand in the salinity and in the pressure gradients there may be some periods of about 3 years[13]).

It should be noted that a 3-year period has

[13]) Aage J. C. Jensen: Periodic Fluctuations in the size of various stocks of fish and their causes. — Medd. f. Komm. f. Danmarks Fiskeri- og Havundersøgelser. Ser. Fiskeri, Bd. IX, Nr. 5, 1933.

## Table 41.

5-year means of bottom salinity (tenths of $^0/_{00}$) at Anholt Knob (28 m.) and Schultz Grund (26 m.) f each quarter and for the year.

| | Anholt Knob | | | | | Schultz Grund | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | year | 1st | 2nd | 3rd | 4th | y |
| 1880—84 ..... | 315 | 329 | 322 | 324 | 322 | 278 | 313 | 323 | 303 | 3 |
| 1885—89 ..... | 324 | 335 | 324 | 324 | 327 | 305 | 327 | 320 | 307 | 3 |
| 1890—94 ..... | 328 | 339 | 326 | 328 | 330 | 296 | 327 | 327 | 298 | 3 |
| 1895—99 ..... | 329 | 336 | 325 | 323 | 328 | 287 | 322 | 313 | 290 | 3( |
| 1900—04 ..... | 328 | 335 | 323 | 327 | 328 | 301 | 324 | 308 | 301 | 3( |
| 1905—09 ..... | 323 | 334 | 319 | 326 | 326 | 289 | 321 | 305 | 308 | 3( |
| 1910—14 ..... | 320 | 327 | 325 | 321 | 323 | 294 | 313 | 315 | 305 | 3( |
| 1915—19 ..... | 322 | 329 | 319 | 319 | 322 | 300 | 327 | 314 | 296 | 31 |
| 1920—24 ..... | 321 | 329 | 318 | 321 | 322 | 298 | 322 | 306 | 291 | 3( |
| 1925—29 ..... | 317 | 327 | 318 | 319 | 320 | 294 | 326 | 310 | 294 | 3( |
| 1930—34 ..... | 328 | 333 | 332 | 330 | 331 | 299 | 328 | 317 | 302 | 31 |

been determined by Borowik[14]) in the flow of water of the Vistula.

**2.** Lower layer in the Kattegat.

It is seen from Figures 8 and 13 that the secular variations of salinity have been substantially different in the northern and southern Kattegat. The difference can be explained mainly by the different way in which the wind (the pressure gradients) and the precipitation of the Baltic influence the two localities in connexion with the difference in the annual variation of the inflow. The variations from year to year in salinity at the Anholt Knob and Læsø Rende, Bottom, turned out to show a particularly distinct co-variation with the pressure gradient Fanø—Copenhagen. Also the secular changes of salinity at the Anholt Knob and Læsø Rende, Bottom, show a high degree of conformity with the pressure gradient Fanø—Copenhagen. This northerly component of the wind has been decreasing from 1880 to 1900, but during this century it rose rather smoothly until about 1927; after that it decreased, and in course of a couple of years it had been converted into a southerly component. *Correspondingly, the salinity at the Anholt Knob, Bottom, was increasing from 1880 to 1900 and sinking until about 1927; then it rose quickly, and since 1929 high values prevail* (cp. Tables 41 and 48).

From a comparison between the variations in salinity in later years at Læsø Trindel—Anholt Knob, Bottom, and the variations at Fladen, 30 and 40 m., it is possible to state the variations in the lower current through the Northern Kattegat during later years. Most regrettably the observations at Fladen do not date further back than 1923.

The isohalines in the lower layer across Kattegat at Fladen seem to have been nearly horizontal prior to 1929, in any case the eastward slope ha been very slight. An exact statement of the declir is not possible as the observations at Læsø Trindel and Anholt Knob do not reach deeper than 20 an 28 m. respectively.

On the other hand it is quite certain that in th years 1929—33 a westward rise has been ver marked. A calculation of the anomaly of salinit Læsø Trindel—Anholt Knob, Bottom, from th salinity at Fladen, Bottom, gives very much lowe values from 1923 to 1929 than later on. Th deviations from mean of these anomalies sinc 1924 are recorded in Table 42.

## Table 42.

Salinity (tenths of $^0/_{00}$) at Fladen, Bottom, an deviation of salinity at Læsø Trindel—Anholt Knob Bottom, from salinity at Fladen (see text).

| | Salinity, Fladen, 40 m. | | | | Anomaly of salinity Læsø Trindel—Anholt | | | |
|---|---|---|---|---|---|---|---|---|
| Quarter: | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4 |
| 1924 .. | — | — | 331 | 336 | — | — | —4 | — |
| 1925 .. | 330 | 340 | 334 | 332 | 0 | —3 | 5 | |
| 1926 .. | 339 | 341 | 332 | 332 | —1 | —4 | —4 | — |
| 1927 .. | 330 | 333 | 333 | 336 | —4 | —6 | —9 | — |
| 1928 .. | 336 | 344 | 329 | 337 | —9 | —5 | —3 | — |
| 1929 .. | 337 | 341 | 329 | 330 | 0 | 2 | 2 | — |
| 1930 .. | 336 | 344 | 337 | 333 | —7 | 3 | 7 | |
| 1931 .. | 335 | 340 | 333 | 329 | 7 | 5 | 5 | |
| 1932 .. | 329 | 343 | 337 | 333 | 4 | 4 | 1 | |
| 1933 .. | 339 | 341 | 337 | 343 | 13 | 4 | 2 | |

*Thus we can state that the increased salinity of the later years in the Northern and Middle Kattegat are due to an increased inflow.*

The salinity in the lower layer of Fladen has been more or less even through these years, the increase in the salinity at the western side of the deep channel of the Eastern Kattegat thus is due to an actual increase in the strength of the saliferous water body.

*At the Schultz Grund, Bottom, however — the*

[14]) J. Borowik: Periodicité des Fluctuations du Reflux de la Vistula. — Bull. Inst. Oceanogr. No. 579. Monaco 1931.

*ular changes of the annual mean salinity are s pronounced,* in accordance with the already ntioned fact, that the salinity, primarily deter- ned by the salinity of the northern Kattegat, is luenced by the Baltic precipitation-current as l as the wind-current, sometimes counteracting h other.

In the northern Kattegat the bottom salinity varied — secularly — considerably from arter to quarter, and at Schultz Grund, Bottom, y great differences are recorded in the secular inity variations. It seems, that the secular iations in wind and precipitation are of siderable importance to explain the secular iations in bottom salinity in the different arters also — duly considering the facts recorded section IV as to dependence on determining tors.

Yet the causal dependency of the variations in salinity in the single quarter of the year from salinity variations at bottom and surface is y complicated, and the more so if we consider dependency on the current producing factors. An exact derivation of the secular variations in inity from its causes, therefore, has not been ried out.

More simple is the dependency if we consider five year means.

The variations of annual mean-salinity at Anholt ob, Bottom, is essentially determined by the iations in the northerly component of the wind ressure difference Fanø—Copenhagen). If we ulate the correlation coefficient between this ference and the salinity at Anholt Knob, Bottom. find $r = -0{\cdot}83$ (11 pairs of observations). By ans of the regression coefficient we may cal- ate the salinity from the pressure difference and

## Table 43.

ear means of annual mean salinity ($^0/_{00}$) at holt Knob, Bottom, observed and calculated from difference of air-pressure Fanø—Copenhagen.

| | Observed | Anomalies observed | Anomalies calculated |
|---|---|---|---|
| 80—84 ..... | 32·2 | —0·3 | —0·1 |
| 85—89 ..... | 32·7 | 0·2 | 0·2 |
| 90—94 ..... | 33·0 | 0·5 | 0·5 |
| 95—99 ..... | 32·8 | 0·3 | 0·1 |
| 00—04 ..... | 32·8 | 0·3 | 0·0 |
| 05—09 ..... | 32·6 | 0·1 | —0·3 |
| 10—14 ..... | 32·3 | —0·2 | —0·2 |
| 15—19 ..... | 32·2 | —0·3 | —0·3 |
| 20—24 ..... | 32·2 | —0·3 | —0·3 |
| 25—29 ..... | 32·0 | —0·5 | —0·4 |
| 30—34 ..... | 33·1 | 0·6 | 0·5 |

the values shown in Table 43. *It is very remark- e that the dependence on the wind seems to plain the secular variation of the salinity at bottom.* The salinity at Schultz Grund, Bottom, naturally is very much dependent on the salinity at more northerly parts of the Kattegat. The anomaly in salinity of Schultz Grund, Bottom, from the salinity at Anholt Knob, Bottom, is mainly determined by the salinity at surface, and the correlation coefficient between the said salinity anomaly and the surface salinity at Schultz Grund is $r = -0{\cdot}63$. In Table 44 the anomaly has been calculated from surface salinity.

## Table 44.

Difference ($^0/_{00}$) between annual mean of salinity at Anholt Knob and Schultz Grund, Bottom, observed, and calculated from surface-salinity at Schultz Grund.

| | Observed | Calculated |
|---|---|---|
| 1880—84 ..... | —0·7 | —0·6 |
| 1885—89 ..... | —0·4 | —0·5 |
| 1890—94 ..... | 0·1 | —0·2 |
| 1895—99 ..... | 0·8 | 0·0 |
| 1900—04 ..... | 0·2 | 0·4 |
| 1905—09 ..... | 0·3 | 0·1 |
| 1910—14 ..... | —0·1 | 0·2 |
| 1915—19 ..... | —0·5 | —0·3 |
| 1920—24 ..... | 0·1 | 0·1 |
| 1925—29 ..... | —0·1 | 0·2 |
| 1930—34 ..... | 0·3 | 0·1 |

The faunistic character of the Transition Area inflow is dependent very much on the inflow to the North Sea. As to this, our knowledge is rather deficient, and the following exposé therefore more or less hypothetical. The secular changes are further elucidated in the paper: "Seasonal guests in Transition area" in this volume.

At an average the winds blowing over the North Sea and the Transition Area are western or south-western.

A southwesterly wind in the North Sea, as in the Kattegat, will strengthen the currents. Water will be forced towards N. E. and a stronger inflow will be the consequence. This inflow from the north consists partially of water from the North-Atlantic drift-current, the "Gulf-stream", partially of water from the deeper layer of the Norwegian Sea.

With western as well as southwestern resulting winds the character of the inflow is determined by the strength of the wind. The stronger the wind the more the Gulf-stream water will predominate. A very strong western wind will, moreover, have an intensifying effect on the inflow as a whole.

During the period since 1880, resulting south-western winds have prevailed in the years 1880—1904 and in 1930—34, western winds in 1905—29. The force of the resulting wind has been greater than normal in the quinquennium 1890—94 and after 1920, especially in 1930—34. Consequently

rather strong inflows have occurred in the periods 1880—1904 and since 1920, especially in the latest quinquennium.

During the quinquennium 1890—94, the resulting wind was southwestern and very strong. Perhaps this may explain the comparatively great masses of 34 $^0/_{00}$ salinity and of "bank-water" of 32 and 33 $^0/_{00}$ salinity found by O. Pettersson and G. Ekman in some of these years[15]). The southeastern direction of the wind will cause a comparatively great amount of the water forced into the Skagerak, derived from the Southern North Sea, and therefore less saline. Moreover the strong southwestern wind has checked the flow of the Norwegian coastal current in the Skagerak (the Baltic current) and has spread its water towards the southern Skagerak and mixed it with the water of the Jutland current.

If hydrographic conditions, similar to those found in the quinquennium 1890—1894, have existed in the Skagerak during the whole period 1876—1896, as stated by Pettersson, it seems necessary to explain it by assuming a change in the inner processes in the sea, — as done by Pettersson.

*In the Kattegat the wind will bring about stronger currents the more it has been South of West. This occurred 1880—1905, and the inflow and the salinity at bottom consequently was rather great. During 1905—28 the resulting direction of the wind was more westerly. Out and inflow was on the whole weaker. A very strong inflow has taken place during 1929—34, due to the prevailing strong southwestern winds.*

As to the cyclic periods in the wind and in the salinity is referred to the preceding section. Besides the regular change possibly corresponding to a 35-year Brückner's period there may seem to be a great many different shorter periods, possibly due to the interference of various regular periodic fluctuations.

### 3. Comparison between secular variations in salinity in the Kattegat, and in the North Sea.

The survey given by Jacobsen[16]) of the variations of the salinity in the North Sea during 1901—1928 enables us to compare the variations in that Area with those recorded in the Transition Area.

The shorter fluctuations of the surface salinity in the Kattegat from year to year seem to be simila to those found in the Eastern and Central North Se partially also in the Southern North Sea and th Channel. High values are observed about 190 1908, 1912, 1915, 1921—22, 1925 and 1928—30 In the Central North Sea high values were als found in 1907 and 1920. In the Eastern North Se the maximum in 1915 is not very marked.

In the channel and the Southern North Sea th current, and without doubt also the salinity, i determined by the western winds[17]), which als influences the variations in the Transition Area Also the influence of wind and precipitation ma be supposed to be somewhat similar in the Easter and Central North Sea as in the Transition Area

The secular trend of the surface salinity in th Kattegat, on the other hand, is rather different fro those found in the North Sea during 1901—28. A mentioned above, specially high values were foun in the surface-salinity in Kattegat about 1890 an 1920, in the Channel and Southern North Sea a the beginning of this century and about 1922. Fo these areas in the North Sea Jacobsen[16]) ha stated that the secular change may be due to regular period of 19 years periodicity in the tida producing force.

*The secular change in salinity at Schultz Grund Bottom, is partly the reverse of that recorde in the English Channel* by Jacobsen[16]) an Lumby[18]). Corresponding to the high salinitie in the Channel 1921—23 a pronounced minimun was found at Schultz Grund, Bottom. As show above, the salinity at Bottom is determined by th wind in such a way that there is a negative correla tion between westerly wind and the salinity whil the inflow through the Channel is regulated directl by the western winds[17]). On the other hand, n minimum was found corresponding to the maximun in the salinity in the Channel 1903—09. During these years no especially strong western winds occurred (except in the 1st quarter of the year) and the maximum of salinity in the Channel in

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[15]) O. Pettersson: Om det Bohuslänske sillfiskets periodicitet. — Ur svenska hydrografisk-biologiska Kommissionens Skrifter. Göteborg 1922, p. 14.

[16]) J. P. Jacobsen: Temperature and Salinity at the Surface of the North Sea and the English Channel. Conseil Perm. Internat. pour l'Exploration de la Mer. Copenhague 1934.

[17]) As to the dependency: see J. N. Carruthers: The water Movement in the Southern North Sea. Part I The Surface Drift. — Min. of Agric. and Fisheries. Fishery Invest. Ser. II. Vol. VIII, No. 2, 1925. A wrong citation from this paper as to the dependency most regrettably has occurred in my paper: Periodic fluctuations etc. — Medd. f. Komm. f. Danmarks Fiskeri- og Havundersøgelser, Ser. Fiskeri. Bd. IX, Nr. 5, 1933, p. 21. C. has not written that the effect on the current of N. E. winds seems to be more pronounced than the effect of winds about S. W.

Moreover is referred to J. N. Carruthers: The Flow of Water through the Straits of Dover etc. — Min. of Agric. and Fisheries. Fishery Invest. Ser. II, Vol. XIV, No. 4, 1935, p. 32, where a summary of the connexion between the yearly range of wind, current and salinity has been given.

[18]) J. R. Lumby: Salinity and Temperature of the English Channel. — Ministry of Agric. and Fisheries. Fishery Invest. Ser. II, Vol. XIV, No. 3, 1935.

eginning of the century thus very likely must cribed to other factors than those determining ecular change of the bottom salinity in the ern Kattegat.

n the Northern and Middle Kattegat (the Ska- Rev L. V. and Anholt Knob L. V.) at bottom, e the dependency on the westerly wind is marked, also the secular variation is different. nholt Knob, Bottom, low salinities were found —16 and 1922—28. The dependency of the ern component of the wind has been referred ove.

he very high salinities in the lower layer ded in the Kattegat during later years cor- nd to the high values in the Northern North f some of these years demonstrated by T a i t v. R i e l[19]), and no doubt are due to the g resulting southwestern winds.

### alinity and inflow into the altic.

rom Figure 6 it appears that *the salinities at s of more than 40 m., N. W. of Bornholm, to have been higher in the years after 1920 before 1914;* a similar statement cannot be as to the area E. of Bornholm, but this is ps due to the infrequency of observations.

s will appear from the statement in section IV, it seems that from the variations of salinity ogden (and Gedser), combined with the varia- of observed current it was possible to state if flow had taken place. On account of the ency in the observations of current and ty they cannot be used for this purpose. No the observations of wind constitute a more tive measure although in this case, too, force direction were determined by estimate only.

very rough picture of the change in inflow e obtained from the number of cases in which v has been stated by the contemporary con- ation of salinity and current. If we compare umbers of inflow in the different 5-years with ressure difference Fanø—Skaw we get:

| | Pressure difference thirtieths of mm. | Number of inflows |
|---|---|---|
| 900—04 ..... | 25 | 7 |
| 905—09 ..... | 30 | 7 |
| 910—14 ..... | 32 | 6 |
| 915—19 ..... | 34 | 6 |
| 920—24 ..... | 52 | 8 |
| 925—29 ..... | 58 | 9 |
| 930—34 ..... | 59 | 11 |

J o h n B. T a i t: Salient Features of the Hydro- of the Northern North Sea and the Faroe—Shetland el in 1935. — Journal du Conseil. Vol. XI. No. 2, P. M. v. R i e l: Variations in Temperature and y in the Northern North Sea. — Journal du Conseil. I, No. 2, 1936.

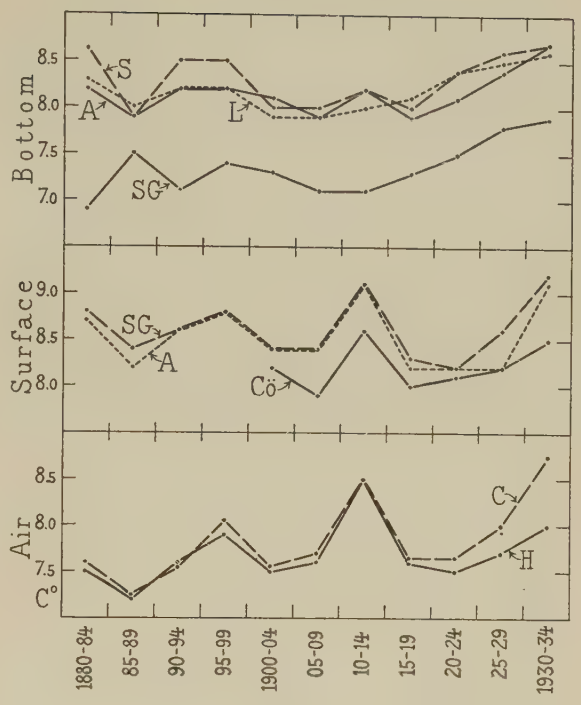


Fig. 9.

5-year means of air temperature at Copenhagen (C) and Hammershus, Bornholm (H), of surface temperature at Schultz Grund (S. G.), Anholt Knob (A), and Christiansø (Cø), and of bottom temperature at Skagens Rev (S), Læsø Rende (L), Anholt Knob (A) and Schultz Grund (S.G.).

It should be noted that the *resulting* current calculated from the wind by means of the formula given by J a c o b s e n (comp. section IV. D, 2) gives a somewhat different secular variation with the weakest resulting (outgoing) current during the quinquennium 1920—24, 4·8 cm./sec. at an average for the year, and high values during 1900—04 and 1930—34, 7·7 and 7·5 cm./sec., respectively.

## B. Secular changes of the temperature.

### 1. Temperature of the air.

The temperature of the surface water shows a very marked co-variation from one year to another with that of the atmosphere, but the concurrence of the secular changes is partial only. A look at the means of the 5-year periods of Fig. 9 will show that the trend of the air temperature movement has been rising during the last 50 years and considerably below normal during the period 1880—1895. If we look at the air temperature of the different seasons shown in Fig. 10 we see that especially in winter the temperature has been rising, the winter temperature of the last 15 years showing

an average rise of 1° as compared to the years 1870—94. Also in spring the temperature has been rising, but only about ¾° during the same period. An even smaller rise of the temperature of the air is found in autumn with about ½° from 1870 till 1900, and during the last 30 years the temperature has shown a falling tendency.

In summer there has been no continued secular rise of the air temperature during the last 70 years. Of longer periods in the temperature there seems to have been a 15—20-year period in autumn, winter and spring. It may seem to co-variate with the 18·5-year period found by D'Arcy Thompson in the water level[20]), the minima of temperature occurring simultaneous with minima of the moon's inclination to the ecliptic. Later on the occurrence of the same period has been studied by B. Storrow[21]), and le Danois has given a schematic survey of the variation[22]).

Moreover a period of about 9—10 years seems rather clear in the air temperature both in winter and summer. An exact determination of the leng of the period has not been tried, and thus it not as yet possible to decide whether it is t 10-year Pettersson Period[23]) or the 9-ye period found by Storrow (1. cit. 1925), of t same length as the "Nodabsidperiod" of Petter son. On the other hand there is in the a temperature no indication of Brückner's peri of 35 years. The secular change with minimu about 1885 and maximum about now seems to l a part of a longer period of somewhat more th 100 years as that found by Ljungmann ar Pettersson[24]). According to the survey of ic winters given by Speerschneider the ten perature of the winters was low about 1770, hig about 1820[25]). During the last 50—60 years *th climate has become more oceanic with the risin*

[20]) D'Arcy Thompson: On mean sea level and its fluctuations. Fish. Board for Scotland, Scient. Invest. No. IV, 1915, p. 32 et seq.

[21]) B. Storrow: Fluctuations in Fisheries. Transactions of the Natural History Society of Northumberland, Durham and Newcastle upon Tyne. New Series Vol. VI, Part II. 1925.

[22]) E. le Danois: Les transgressions océaniques. Revue des Travaux de l'Office des Pêches Maritimes. Paris 1934.

[23]) Otto Pettersson: Klimatets Rörlighed. E Studie i Geofysik. Göteborgs Kungl. Vetenskaps- och Vitte hets-Samhälles Handlingar. 5 Flg. Ser. B. Bd. 4 No. Göteborg 1935, p. 27.

[24]) Otto Pettersson: Über die Wahrscheinlic keit von periodischen und unperiodischen Schwankunge in dem atlantischen Strom und ihre Beziehungen z meteorologischen und biologischen Phänomenen. Svensk hydrogr.-biol. Komm. Skrifter. Vol. II. 1905.

Hans Pettersson: Long Periodical Variations o the Tidegenerating Force. Publ. de Circonstance. No. 6 1913.

[25]) C. I. H. Speerschneider: Om Isforholdene danske Farvande i ældre og nyere Tid. Aarene 690—186 Publikationer fra Det danske meteorologiske Institut. Med delelser. Nr. 2, 1915.

## Table 45.

5-year means of annual mean-temperature (C.°) of the air (average of Tarm and Copenhagen (Landbohøjskolen)), and differences between surface temperature of Kattegat and the air temperature. Corresponding 5-year means of air temperature at Bornholm (Hammershus) and of surface-water at Christianso and the differences between these.

| | Air temperature Tarm — Landbohøjskolen | | Difference surface temperature—air temperature Tarm—Landbohøjskolen | | | Air temperature | Temperature at surface | Diffe-rence |
|---|---|---|---|---|---|---|---|---|
| | | | Schultz Grund | Anholt Knob | Skagens Rev | Hammershus | Christianso | |
| 1860—64 | 7·2 | | | | | | | |
| 1865—69 | 7·4 | 7·3 | | | | | | |
| 1870—74 | 7·3 | | | | | | | |
| 1875—79 | 7·0 | | | | | 7·2 | | |
| 1880—84 | 7·6 | 7·1 | | 1·3 | 1·5 | 7·5 | 8·3 | 0·8 |
| 1885—89 | 6·8 | | 1·2 | 1·4 | 1·6 | 7·2 | 8·4 | 0·8 |
| 1890—94 | 7·4 | | 1·2 | 1·2 | 1·1 | 7·6 | | |
| 1895—99 | 7·8 | 7·6 | 1·0 | 1·0 | 1·1 | 7·9 | | |
| 1900—04 | 7·5 | | 0·9 | 0·9 | 1·0 | 7·5 | 8·3 | 0·8 |
| 1905—09 | 7·5 | | 0·8 | 0·9 | 1·3 | 7·6 | 7·9 | 0·3 |
| 1910—14 | 8·4 | 7·8 | 0·6 | 0·7 | 0·9 | 8·5 | 8·8 | 0·3 |
| 1915—19 | 7·4 | | 0·8 | 0·8 | 0·9 | 7·6 | 7·8 | 0·2 |
| 1920—24 | 7·5 | | 0·6 | 0·7 | 0·8 | 7·5 | 7·6 | 0·1 |
| 1925—29 | 7·6 | 7·8 | 0·9 | 0·6 | 0·8 | 7·5 | 7·9 | 0·4 |
| 1930—34 | 8·4 | | 0·9 | 0·7 | 0·8 | 8·0 | 8·5 | 0·5 |

*ponderance of the western winds. Simultaneous
h the rise of the temperature there is an increase
he quantity of precipitation*, which is contrary
he scheme of B r ü c k n e r where warm and dry
iods alternate with cold and humid ones.

T e m p e r a t u r e o f s u r f a c e w a t e r.

*The pronounced rise of the temperature of the
osphere is not observed in the surface tempera-
of the Kattegat water* (cp. Fig. 9 and Table
. The annual mean temperature of the air is
ays below that of the water, but the difference

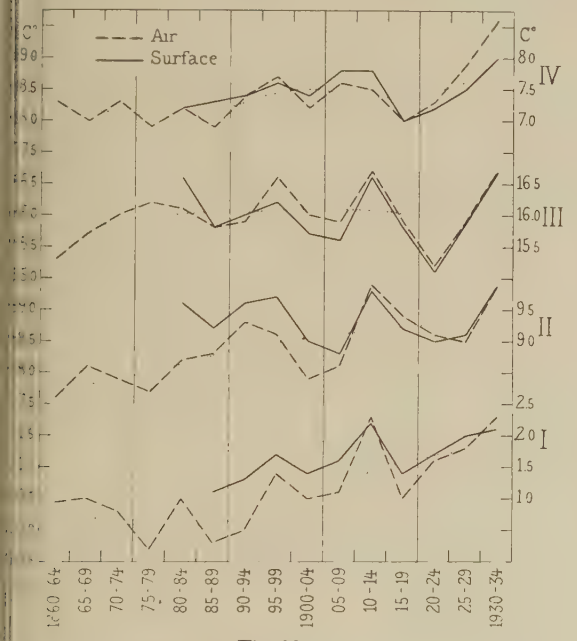


Fig. 10.
ar means of quarterly air temperature at Copenhagen
ndbohøjskolen) (dotted), and of surface temperature
at Schultz Grund (full).

considerably greater before 1895 than after
t year. In the present century the differences
ween the temperatures of atmosphere and sur-
e water have been subject to very great changes,
show no rising or falling tendencies as will be
n from Table 45.

The fact that the remarkable secular rise in the
peratures of atmosphere was not found in the
perature of the water may be accounted for by
higher salinity of the Kattegat before 1895.
s higher salinity was undoubtedly caused partly
the inferior precipitation partly by the pre-
nderance of western winds during some of those
rs. The "continental" influence of the meteoric
er was thus smaller before 1900. If we look at
individual quarters of the 5-year means of the
face temperature (Fig. 10) we note that while
most distinct rise of the air temperature is
nd in winter, the secular change of the
temperature of the water in this season has been inconsiderable. During this time the water is cooled by the air, but the temperature of the water in contradiction to that of the air has a nether limit as it can only fall to about 1° or ½° C below zero, therefore the secular variation of the water must be less at this season than that of the air temperature.

At Christiansø, however, the annual mean temperature of the surface water has been falling, thus contrasting with that of the air, which shows a rising tendency also in this locality. Here, too, this fact is accounted for by the contemporary change of salinity, the connexion being rather complex. If the high salinities are due to strong vertical mixing the temperature should be low, if due to a decrease in precipitation the continental influence is diminished and the temperature should be correspondingly higher.

Thus the high salinities of the eighties of the past century, as we have seen above, may be ascribed to a minimum precipitation. The surface temperature, correspondingly, was higher than might be expected from the air temperature. During this century the changes in salinity are due mainly to changes in intermixture between the water layers, and now low salinities correspond to great differences between the temperature of water and air.

As will appear from Fig. 10 the changes of the difference between the temperature of air and water is found chiefly in the 2nd and 3rd quarter.

In the surface temperature we found the great secular rise of the air temperature from the eighties up to now to a minor degree only. On the other hand all shorter periods found in the air temperature, mentioned above, are clearly visible.

**3.** T e m p e r a t u r e i n l o w e r l a y e r s.

The 5-year mean of the annual temperature at the bottom of the Northern Kattegat (the Skaw, Læsø Rende and Læsø Trindel) shows much the same variations from one quinquennium to the other as the temperature of the air (Fig. 9).

The temperature of the water flowing in from the North Sea will be of comparatively great importance for the temperature of the lower layer of this region. The water temperature of the southern North Sea shows a very great conformity with the temperature of the atmosphere.

In the surface temperature of the Kattegat the great secular change found in the air temperature is hardly to be seen; neither do we find it in the bottom temperature.

On the whole, the bottom temperature becomes the higher the stronger the inflow of oceanic water has been. Therefore the general trend of the temperature at bottom — to a certain degree — has been the same as that of the bottom salinity, with high values in the eighties and nineties.

As was the case at the Skaw the annual mean

temperature of the water at the Læsø Rende and Anholt Knob is higher than that of the air because the strongest inflow takes place in summer. At the Schultz Grund, however, where the lower current is weak in summer and the bottom water partially stagnant during this period (cp. Jacobsen 1908, p. 25[8])), we find a comparatively low annual mean temperature (Table 46).

## Table 46.

Difference (in C.°) between airtemperature (mean Tarm—Copenhagen (Landbohøjskolen)) and bottom temperature at Skagens Rev, Anholt Knob, and Schultz Grund, in 5-year periods.

| | Skagens Rev | Anholt Knob | Schultz Grund |
|---|---|---|---|
| 1880—84 .... | 1·0 | 0·7 | —0·7 |
| 1885—89 .... | 1·1 | 1·2 | 0·7 |
| 1890—94 .... | 1·1 | 0·8 | —0·3 |
| 1895—99 .... | 0·7 | 0·4 | —0·4 |
| 1900—04 .... | 0·5 | 0·4 | —0·2 |
| 1905—09 .... | 0·5 | 0·4 | —0·4 |
| 1910—14 .... | —0·2 | —0·4 | —1·3 |
| 1915—19 .... | 0·6 | 0·7 | —0·1 |
| 1920—24 .... | 0·9 | 0·9 | 0·0 |
| 1925—29 .... | 1·0 | 0·9 | 0·2 |
| 1930—34 .... | 0·3 | 0·2 | —0·5 |

On account of the complexity of the manner in which the temperature at bottom is determined by the different factors, the details in the temperature variations at bottom in the Northern and the Southern Kattegat are difficult to explain. Some main features, only, should be considered here.

In 1910—14 the temperature of the air and at the surface was very much higher than normal but the temperatures of these bottom waters at Anholt Knob and Schultz Grund were not higher (cp. Table 47). This difference is explained by the temporary variations in the salinity. In 2nd quarter there exists a positive correlation between salin and temperature of the water, the salinity w extraordinarily low thus giving a very low tempe ture. In 3rd quarter a negative correlation is fou between salinity and temperature, and during t said quinquennium a very high salinity caused very low temperature.

In the quinquennium 1930—34 the high te perature of the air has been able to bring abo a high temperature of the water. In this peri high salinities prevailed during all quarters, t influences of the salinities on the temperature summer and winter, respectively, have compensat each other.

On account of the different effect on the te perature of an inflow at the various seasons, an also of the fact that the temperature at bottom determined partially by the temperature of the a (by the inflow from the North Sea and Skagera and by vertical convection), the secular changes the bottom temperature differ from those found i the salinity.

Moreover the difference in the annual period o the inflow is the cause of differences in the secula changes in the Northern and Southern Kattegat.

In the two 5-year periods 1920—29, on th other hand, the temperature of the bottom water i higher than could be expected from the temperatur of the air, which corresponds to the fact that i summer comparatively low salinities have occurre at bottom during this period.

On account of this combined effect of the ai temperature and the inflow on the whole the tem perature of the bottom water of the present century has been rising, especially since about 1915 showing values constantly increasing above normal (cp. Table 47).

The briefer periodicities of 18 and 10 years are easily recognisable in the water temperature — the former at surface as well as bottom, the latter in winter at bottom particularly.

## Table 47.

5-year means of bottom temperature (C.°) at the Skagens Rev (38 m.) and Schultz Grund (26 m.) for each quarter and for the year.

| | Skagens Rev | | | | | Schultz Grund | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | year | 1st | 2nd | 3rd | 4th | year |
| 1880—84 ..... | 4·4 | 7·3 | 13·9 | 8·8 | 8·6 | 3·9 | 5·2 | 9·8 | 8·9 | 6·9 |
| 1885—89 ..... | 4·0 | 6·3 | 12·8 | 8·5 | 7·9 | 4·9 | 5·2 | 10·1 | 10·0 | 7·5 |
| 1890—94 ..... | 4·3 | 7·0 | 13·4 | 9·2 | 8·5 | 4·3 | 4·7 | 9·3 | 10·0 | 7·1 |
| 1895—99 ..... | 4·7 | 6·5 | 13·0 | 9·4 | 8·5 | 4·6 | 5·1 | 10·0 | 9·7 | 7·4 |
| 1900—04 ..... | 4·2 | 6·5 | 12·4 | 9·0 | 8·0 | 4·8 | 4·8 | 10·0 | 9·7 | 7·3 |
| 1905—09 ..... | 4·3 | 6·6 | 12·5 | 8·8 | 8·0 | 4·0 | 4·6 | 10·0 | 9·9 | 7·1 |
| 1910—14 ..... | 4·3 | 7·5 | 12·7 | 8·5 | 8·2 | 4·7 | 4·8 | 9·2 | 9·6 | 7·1 |
| 1915—19 ..... | 4·3 | 6·5 | 12·8 | 8·4 | 8·0 | 4·6 | 5·3 | 9·9 | 9·7 | 7·3 |
| 1920—24 ..... | 4·3 | 7·3 | 13·3 | 8·8 | 8·4 | 4·1 | 5·5 | 10·6 | 10·0 | 7·5 |
| 1925—29 ..... | 4·6 | 7·3 | 13·4 | 9·3 | 8·6 | 4·9 | 5·4 | 10·7 | 10·2 | 7·8 |
| 1930—34 ..... | 5·1 | 7·1 | 13·3 | 9·5 | 8·7 | 5·2 | 5·7 | 10·5 | 10·3 | 7·9 |

Also the 3-year period is seen rather clearly
he temperature of the surface water, especially
vinter.

It may seem that the secular changes in tem-
ature and salinity of the water to a considerable
ree may be derived from changes in the meteorological factors, but that this explanation seems to fail in some cases.

Yet, dependencies of meteorological factors are so conspicuous that *it is necessary to determine them in order to eliminate the effect of these meteorological factors from the observed fluctuations if we wish to investigate supposed fluctuations independent of the meteorological conditions.*

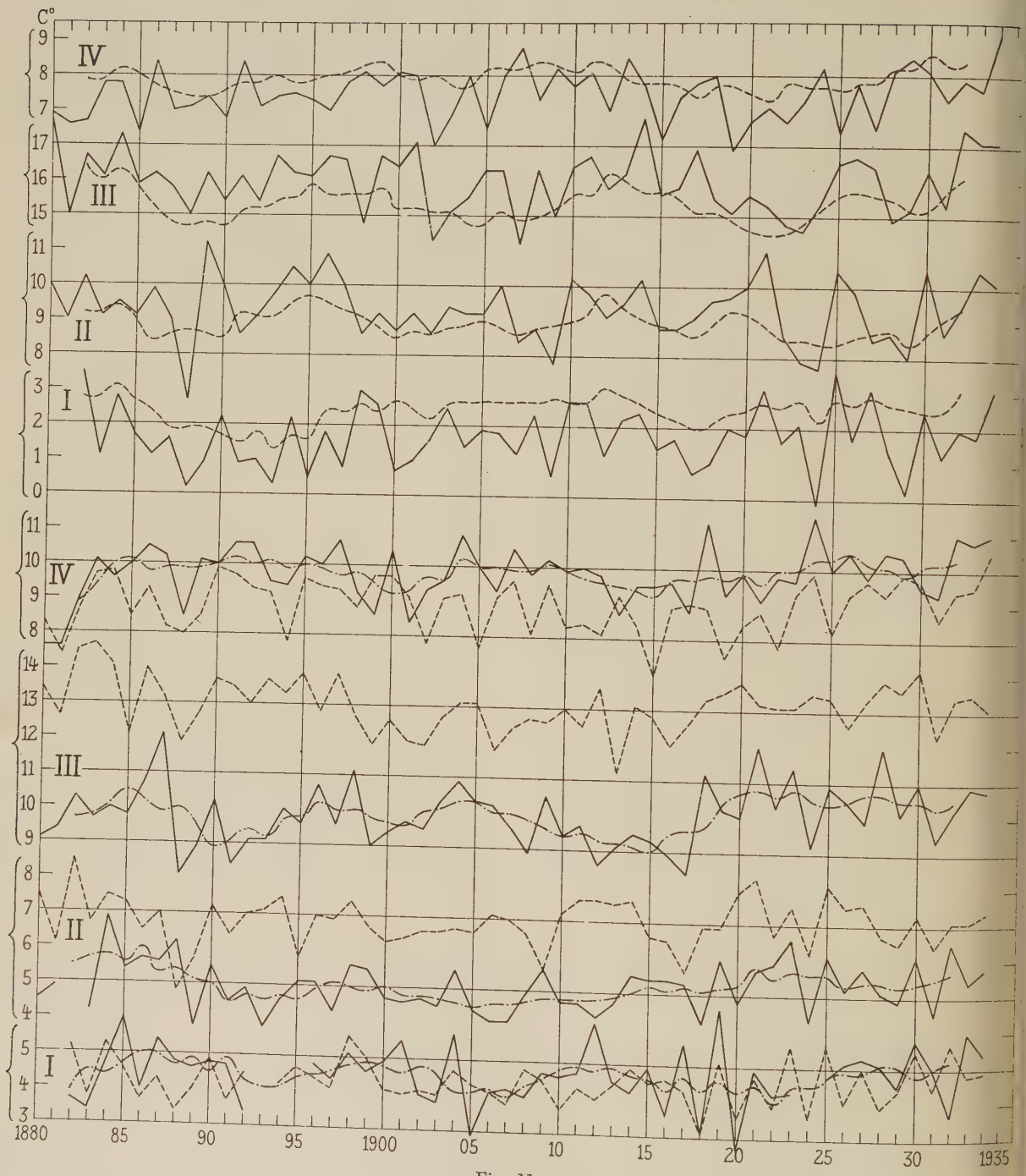


Fig. 11.

Quarterly means of temperature. The upper curves: surface temperature at Schultz Grund, and — smoothed for 5 years — at Skagens Rev (dotted). The lower curves: bottom temperature at Schultz Grund, each year, and smoothed for 5 years (full), respectively, and at Skagens Rev (dotted).

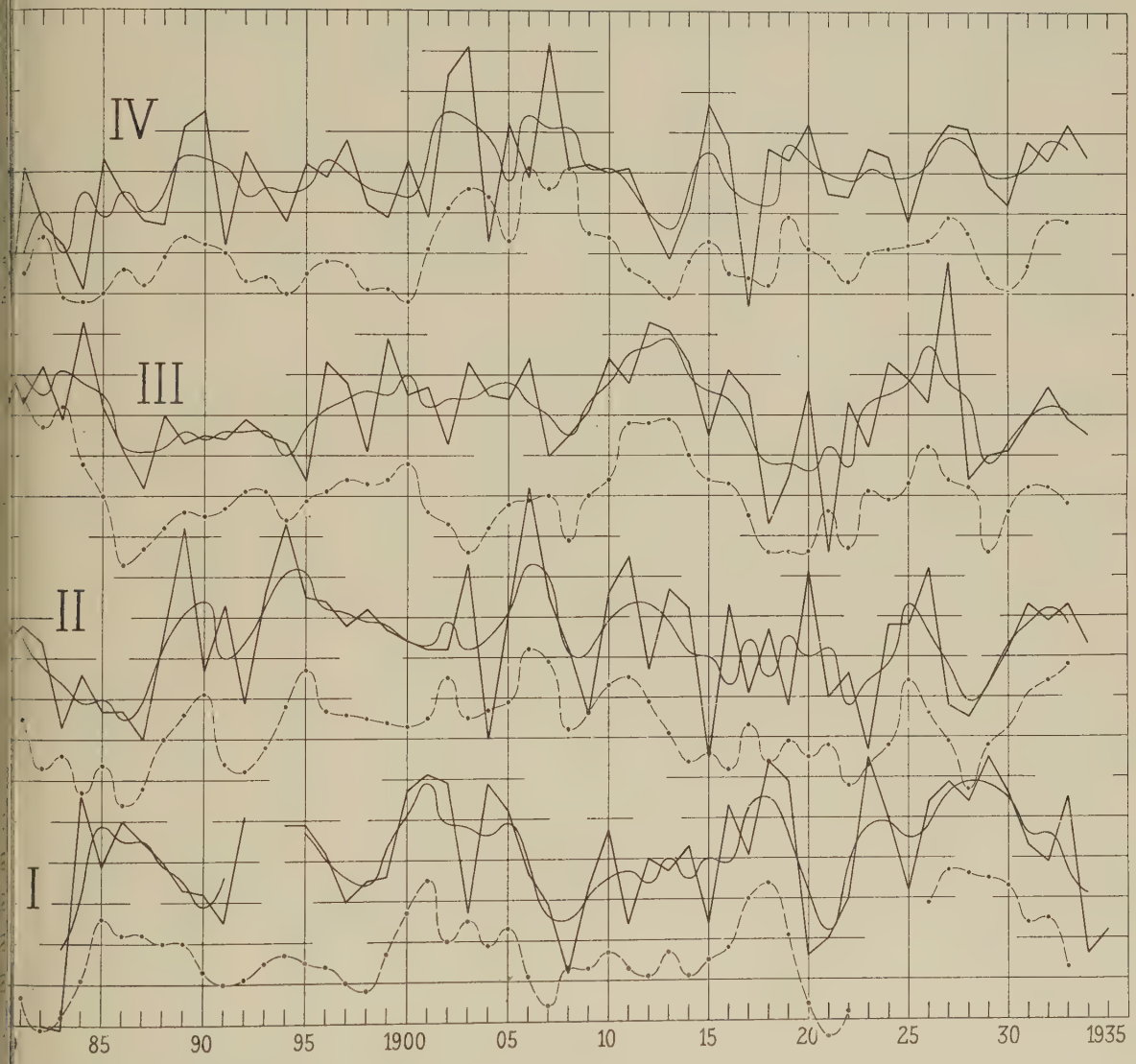


Fig. 12.

arterly means of surface salinity at Schultz Grund (full), and at Anholt Knob (dotted). Continuous curves: smoothed for 3 years.

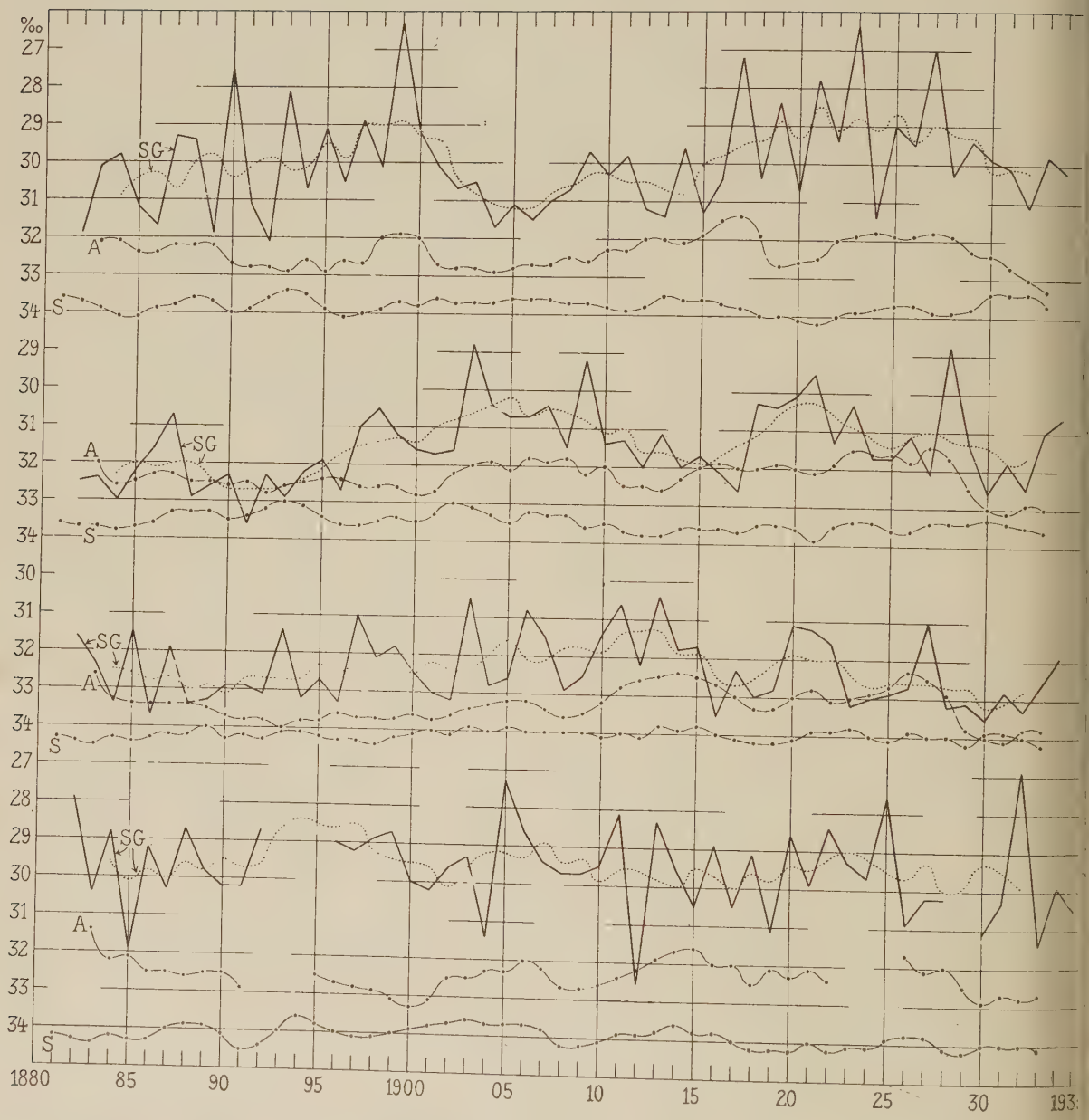


Fig. 13.

Quarterly means of bottom salinity at Schultz Grund (S.G.), each year (full) and smoothed for 5 years (dotted), respectively, and smoothed for 3 years at Anholt Knob (A) and Skagens Rev (S) (nethermost curves: 1st. quarter).

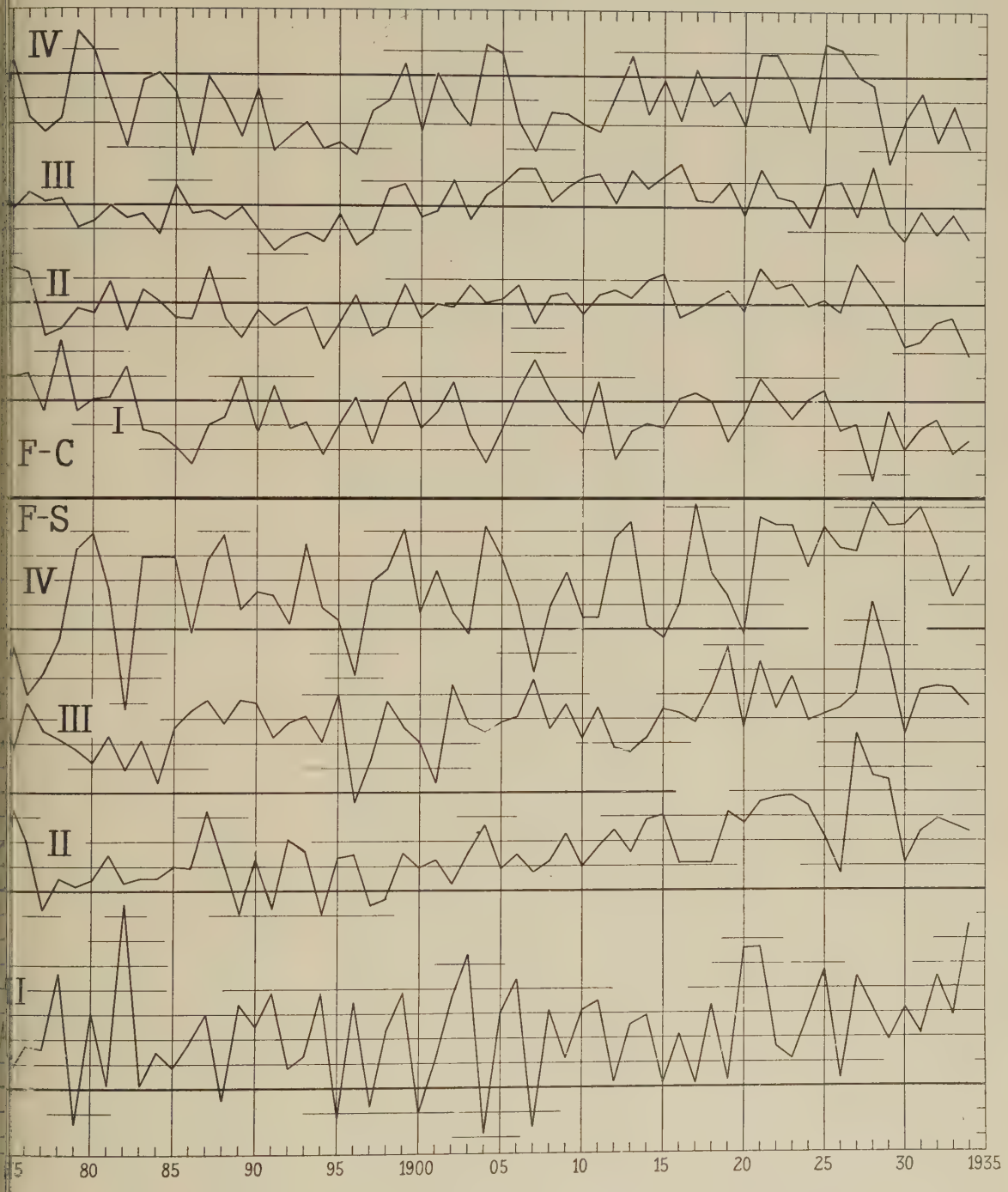


Fig. 14.

terly means of difference in barometric pressure between Fanø and the Skaw (F—S), and between Fanø and Copenhagen (F—C) (tenths of mm.).

**Table 48.**
Quarterly means (in tenths of $^0/_{00}$) of bottom salinity at Anholt Knob L. V. (28 m.) and Schultz Gru

| | Anholt Knob, Bottom | | | | Schultz Grund, Bottom | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4 |
| 1880 | — | 335 | 330 | 327 | — | — | — | |
| 81 | — | — | 322 | 330 | — | — | — | |
| 82 | 302 | 314 | 309 | 324 | 279 | 316 | 325 | 3 |
| 83 | 323 | 333 | 323 | 320 | 304 | 323 | 324 | 3 |
| 84 | 316 | 332 | 328 | 320 | 288 | 334 | 330 | 2 |
| 1885 | 328 | 333 | 327 | 324 | 319 | 315 | 322 | 3 |
| 86 | 318[1]) | 336 | 321 | 328 | 292[1]) | 337 | 316 | 3 |
| 87 | 328 | 332 | 320 | 321 | 303 | 319 | 307 | 2 |
| 88 | 329[1]) | 334[1]) | 327 | 317 | 287[1]) | 334[1]) | 329 | 2 |
| 89 | 321[1]) | 336 | 327 | 328 | 298[1]) | 333 | 326 | 3 |
| 1890 | 326 | 336 | 320 | 320 | 302 | 329 | 323 | 2 |
| 91 | 328[1]) | 340 | 332 | 333 | 302 | 329 | 336 | 3 |
| 92 | 332 | 339 | 324 | 330 | 287 | 331 | 323 | 3 |
| 93 | — | 336 | 328 | 321 | — | 314 | 329 | 2 |
| 94 | 324 | 344 | 327 | 335 | 292 | 332 | 322 | 3 |
| 1895 | 325[2]) | 333 | 320 | 322 | 266[2]) | 327 | 319 | 2 |
| 96 | 326 | 337 | 326 | 330 | 290 | 333 | 327 | 3 |
| 97 | 330[1]) | 334 | 327 | 326 | 292[1]) | 310 | 310 | 2 |
| 98 | 327 | 341 | 325 | 326 | 289 | 321 | 305 | 3 |
| 99 | 331 | 335 | 327 | 309 | 287 | 318 | 312 | 2 |
| 1900 | 334 | 335 | 326 | 323 | 300 | 325 | 316 | 2 |
| 01 | 333 | 338 | 330 | 329 | 302 | 330 | 317 | 3 |
| 02 | 326 | 338 | 325 | 328 | 296 | 332 | 316 | 3 |
| 03 | 317 | 331 | 312 | 326 | 293 | 305 | 288 | 3 |
| 04 | 332 | 332 | 323 | 331 | 314 | 329 | 304 | 3 |
| 1905 | 320 | 333 | 322 | 329 | 273 | 326 | 307 | 3 |
| 06 | 318 | 332 | 318 | 325 | 286 | 308 | 307 | 3 |
| 07 | 322 | 332 | 313 | 326 | 294 | 315 | 304 | 3 |
| 08 | 327 | 339 | 327 | 329 | 296 | 329 | 315 | 3 |
| 09 | 333[1]) | 336 | 313 | 321 | 297[1]) | 325 | 292 | 2 |
| 1910 | 322 | 330 | 327 | 327 | 295 | 314 | 314 | 3 |
| 11 | 322 | 329 | 321 | 320 | 281 | 306 | 313 | 2 |
| 12 | 328[1]) | 326 | 327 | 322 | 326[1]) | 322 | 320 | 3 |
| 13 | 316 | 324 | 327 | 319 | 283 | 304 | 311 | 3 |
| 14 | 314 | 325 | 325 | 318 | 295 | 318 | 320 | 2 |
| 1915 | 320 | 324 | 317 | 325 | 305 | 317 | 317 | 3 |
| 16 | 315 | 327 | 319 | 314 | 289 | 335 | 321 | 3 |
| 17 | 326[2]) | 330 | 321 | 305 | 305[1]) | 323 | 326 | 2 |
| 18 | 320 | 334 | 319 | 323 | 291 | 330 | 303 | 3 |
| 19 | 330 | 334 | 319 | 329 | 311 | 328 | 304 | 2 |
| 1920 | 313 | 325 | 320 | 330 | 286 | 311 | 301 | 3 |
| 21 | 325 | 331 | 321 | 319 | 299 | 312 | 295 | 2 |
| 22 | 324[1]) | 326 | 322 | 325 | 284[1]) | 316 | 313 | 2 |
| 23 | 323[1]) | 332 | 313 | 315 | 293 | 332 | 303 | 2 |
| 24 | — | 330 | 311 | 318 | 297[2]) | 330 | 317 | 3 |
| 1925 | 307 | 325 | 323 | 322 | 276 | 329 | 317 | 2 |
| 26 | 327 | 325 | 315 | 317 | 309 | 327 | 311 | 2 |
| 27 | 316 | 318 | 315 | 317 | 302 | 310 | 321 | 2 |
| 28 | 319 | 331 | 312 | 321 | 302 | 332 | 289 | 3 |
| 29 | 325 | 338 | 325 | 320 | 278[2]) | 331 | 313 | 2 |
| 1930 | 331 | 344 | 338 | 329 | 311 | 335 | 326 | 2 |
| 31 | 330 | 338 | 326 | 324 | 303 | 328 | 318 | 3 |
| 32 | 320 | 341 | 329 | 329 | 269 | 333 | 325 | 3 |
| 33 | 334 | 336 | 332 | 337 | 314 | 326 | 310 | 2 |
| 34 | 327 | 338 | 330 | 332 | 299 | 319 | 306 | 3 |

Note. [1]) and [2]): Observations failing for 1 and 2 months respectively.

**Table 48.**

m.), and means of surface salinity at Skagens Rev, Schultz Grund and Christiansø.

| Skagens Rev, 0 m. | | | Schultz Grund, 0 m. | | | | Christiansø, 0 m. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th |
| 277 | 278 | 320 | 207 | 167 | 164 | 247 | 76 | 77 | 76 | 76 |
| 282 | 289 | 292 | — | 162[1]) | 177 | 199 | 77 | 74 | 75 | 76 |
| 294 | 289 | 281 | 240 | 166 | 168 | 213 | 80 | 79 | 77 | 79 |
| 299 | 306 | 316 | 241 | 187 | 181 | 218 | 79 | 74 | 68 | 74 |
| 290 | 287 | 321 | 183 | 174 | 157 | 229 | 74 | 77 | 77 | 76 |
| 290 | 296 | 301 | 201 | 183 | 178 | 197 | 75[2]) | 77 | 77 | 74 |
| ) 297 | 312 | 297 | 190 | 183 | 189 | 206 | 74[1]) | — | 77[2]) | 79 |
| 305 | 316 | 303 | 195 | 190 | 197 | 212 | — | — | — | — |
| ) 295[1]) | 303 | 311 | 200[2]) | 167[1]) | 180 | 213 | — | — | — | — |
| ) 239 | 295 | 294 | 207[1]) | 138 | 187 | 189 | 78 | 87 | 83 | 81 |
| 285 | 310 | 281 | 208 | 173 | 185 | 185 | 77 | 79 | 88 | 79 |
| ) 249 | 293 | 302 | 215[1]) | 157 | 186 | 218 | 77 | 80 | 86 | 79 |
| 296 | 299 | 296 | 189 | 181 | 181 | 195 | 77 | 79 | 94 | 83 |
| 302 | 297 | 308 | — | 154 | 185 | 204 | — | — | — | — |
| 258 | 302 | 301 | 191 | 137 | 187 | 212 | — | — | — | — |
| ) 293 | 311 | 303 | 191[2]) | 155 | 196 | 198 | — | — | — | — |
| 290 | 292 | 285 | 198 | 156 | 167 | 201 | — | — | — | — |
| ) 279 | 299 | 302 | 210 | 162 | 172 | 192 | — | — | 67 | 71 |
| 274 | 306 | 295 | 205 | 158 | 189 | 208 | 70 | 73 | 74 | 74 |
| 284 | 284 | 313 | 204 | 163 | 161 | 211 | 66 | 64 | 68 | 64 |
| 281 | 293 | 290 | 183 | 166 | 175 | 197 | 66 | 67 | 71 | 64 |
| 271 | 273 | 320 | 179 | 168 | 173 | 211 | 66 | 66 | 69 | 66 |
| 272 | 312 | 268 | 181 | 168 | 187 | 176 | 66 | 66 | 68 | 66 |
| 255 | 282 | 288 | 213 | 147 | 167 | 169 | 67 | 64 | 64 | 63 |
| 298 | 301 | 319 | 181 | 190 | 175 | 217 | 60 | 65 | 66 | 79 |
| 266 | 290 | 289 | 188 | 159 | 176 | 188 | 71 | 66 | 71 | 61 |
| 264 | 289 | 293 | 203 | 128 | 166 | 201 | 66 | 72 | 75 | 72 |
| 276 | 299 | 285 | 211 | 155 | 190 | 168 | 68[1]) | 70 | 77[1]) | 71 |
| 279 | 296 | 291 | 228 | 168 | 185 | 199 | 66 | 68 | 71 | 70 |
| 295 | 296 | 311 | 207 | 184 | 179 | 198 | 67 | 68 | 76 | 73 |
| 265 | 271 | 299 | 193 | 154 | 166 | 200 | 71 | 73 | 74 | 62 |
| 261 | 291 | 303 | 216 | 145 | 172 | 199 | 64 | 65 | 70 | 69 |
| 306 | 298 | 312 | 200 | 173 | 157 | 211 | 71 | 68 | 66 | 62 |
| 268 | 260 | 302 | 203 | 153 | 159 | 221 | 69 | 70 | 75 | 68 |
| 283 | 274 | 288 | 197 | 158 | 167 | 209 | 69 | 75 | 77 | 78 |
| 305 | 298 | 273 | 216 | 195 | 185 | 183 | 75 | 74 | 76 | 72 |
| 289 | 299 | 297 | 187 | 157 | 169 | 193 | 71 | 71 | 71 | 74 |
| 296 | 282 | 327 | 199 | 179 | 175 | 233 | 72 | 75 | 76 | 77 |
| 243 | 320 | 310 | 176 | 163 | 207 | 194 | 76 | 75 | 77 | 77 |
| 306 | 317 | 295 | 181 | 182 | 195 | 197 | 72 | 75 | 72 | 73 |
| 279 | 294 | 264 | 224 | 149 | 174 | 188 | 73 | 73 | 72 | 75 |
| 297 | 328 | 318 | 220 | 180 | 214 | 205 | 77 | 79 | 81 | 80 |
| 280 | 285 | 308 | 210 | 174 | 178 | 206 | 75 | 74 | 77 | 75 |
| 264 | 319 | 312 | 175 | 193 | 188 | 194 | 75 | 75 | 76 | 77 |
| ) 296 | 291 | 306 | 190[2]) | 162 | 167 | 196 | 74 | 71 | 70 | 71 |
| 280 | 301 | 306 | 208 | 162 | 171 | 212 | 75 | 74 | 73 | 70 |
| 264 | 286 | 304 | 186 | 148 | 177 | 195 | 69 | 70 | 70 | 71 |
| 300 | 249 | 263 | 181 | 182 | 142 | 188 | 71 | 70 | 68 | 70 |
| 271 | 312 | 304 | 186 | 185 | 196 | 189 | 70 | 71 | 69 | 67 |
| ) 299 | 312 | 317 | 175[2]) | 177 | 190 | 203 | 69 | 70 | 70 | 71 |
| 268 | 300 | 314 | 184 | 168 | 189 | 208 | 73 | 74 | 70 | 69 |
| 283 | 292 | 305 | 197 | 157 | 181 | 192 | 68 | 69 | 69 | 71 |
| 283 | 289 | 266 | 201 | 161 | 173 | 197 | 74 | 73 | 72 | 71 |
| 284 | 296 | 273 | 185 | 157 | 181 | 188 | 73 | 72 | 70 | 70 |
| 271 | 297 | 310 | 224 | 167 | 185 | 196 | 71 | 71 | 72 | 73 |

**Table 49.**

Quarterly means (in tenths of C.°) of bottom temperature at Anholt Knob L. V. (28 m.) and Schu

| | Anholt Knob, Bottom | | | | Schultz Grund, Bottom | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | |
| 1880 | — | 49 | 114 | 91 | — | 45 | 91 | |
| 81 | — | 52[2]) | 113 | 84 | — | 49[1]) | 94 | |
| 82 | 50 | 66 | 133 | 97 | 37 | 70[2]) | 103 | |
| 83 | 40 | 48 | 140 | 112 | 34 | 42 | 97 | |
| 84 | 56 | 61 | 135 | 118 | 47 | 69 | 100[1]) | |
| 1885 | 50 | 56 | 107 | 102 | 60 | 54 | 98 | |
| 86 | 46[1]) | 51 | 129 | 103 | 40[1]) | 57 | 108 | |
| 87 | 50 | 53 | 123 | 98 | 54 | 56 | 121 | |
| 88 | 54[1]) | 50[1]) | 109 | 93 | 48[1]) | 62[1]) | 81[1]) | |
| 89 | 50 | 39 | 120 | 101 | 46[1]) | 38 | 89 | |
| 1890 | 55 | 56 | 121 | 112 | 48 | 55 | 102 | |
| 91 | 50[1]) | 48 | 120 | 111 | 47[1]) | 45 | 84 | |
| 92 | 51 | 51 | 112 | 112 | 34 | 49 | 91 | |
| 93 | — | 39 | 124 | 109 | — | 38 | 91 | |
| 94 | 47 | 52 | 124 | 85 | 41 | 46 | 100 | |
| 1895 | 54[2]) | 45 | 122 | 110 | 41[2]) | 51 | 96 | |
| 96 | 56 | 53 | 122 | 110 | 48 | 51 | 107 | |
| 97 | 53[1]) | 45 | 122 | 112 | 44[1]) | 43 | 96 | |
| 98 | 58 | 59 | 118 | 95 | 51 | 56 | 111 | |
| 99 | 55 | 51 | 107 | 100 | 46 | 55 | 90 | |
| 1900 | 54 | 49 | 118 | 110 | 49 | 47 | 94 | |
| 01 | 54[2]) | 46 | 108 | 103 | 55 | 46 | 97 | |
| 02 | 46 | 44 | 111 | 93 | 40 | 47 | 95 | |
| 03 | 42 | 51 | 113 | 101 | 38 | 45 | 103 | |
| 04 | 55 | 52 | 115 | 107 | 57 | 55 | 109 | |
| 1905 | 45 | 42 | 113 | 95 | 29 | 44 | 103 | |
| 06 | 47 | 48 | 114 | 101 | 41 | 41 | 102 | |
| 07 | 49 | 45 | 116 | 107 | 42 | 41 | 96 | |
| 08 | 51 | 51 | 109 | 97 | 40 | 49 | 89 | |
| 09 | 57[1]) | 54 | 122 | 108 | 47[1]) | 56 | 105 | |
| 1910 | 47 | 53 | 121 | 95 | 46 | 47 | 94 | |
| 11 | 52 | 58 | 121 | 98 | 47 | 47 | 97 | |
| 12 | 52[1]) | 52 | 126 | 92 | 61[1]) | 43 | 86 | |
| 13 | 54 | 56 | 97 | 93 | 45 | 47 | 91 | |
| 14 | 52 | 55 | 123 | 98 | 42 | 55 | 95 | |
| 1915 | 57 | 48 | 116 | 87 | 49 | 54 | 93 | |
| 16 | 42 | 53 | 112 | 99 | 36 | 54 | 89 | |
| 17 | 56[2]) | 46 | 119 | 102 | 56[1]) | 53 | 84 | |
| 18 | 40 | 52 | 124 | 114 | 30 | 42 | 112 | |
| 19 | 63[1]) | 55[1]) | 129 | 99 | 66 | 60 | 102 | |
| 1920 | 32 | 60 | 122 | 101 | 27[1]) | 48 | 100 | |
| 21 | 53 | 65 | 124 | 105 | 49 | 57 | 120 | |
| 22 | 49 | 52 | 125 | 99 | 42[1]) | 59 | 103 | |
| 23 | 54[1]) | 67 | 121 | 109 | 43 | 66 | 114 | |
| 24 | — | 42 | 119 | 117 | 41[2]) | 43 | 92 | |
| 1925 | 58 | 62 | 120 | 109 | 47 | 61 | 109 | |
| 26 | 49 | 54 | 116 | 108 | 51 | 52 | 105 | |
| 27 | 54 | 60 | 127 | 114 | 53 | 58 | 99 | |
| 28 | 47 | 53 | 122 | 112 | 51 | 51 | 120 | |
| 29 | 55[1]) | 50 | 116 | 109 | 45[1]) | 49 | 101 | |
| 1930 | 59 | 57 | 131 | 104 | 58 | 61 | 110 | |
| 31 | 53 | 50 | 110 | 99 | 50 | 45 | 94 | |
| 32 | 53 | 62 | 130 | 109 | 37 | 65 | 102 | |
| 33 | 60 | 50 | 132 | 109 | 60 | 54 | 109 | |
| 34 | 55 | 58 | 116 | 121 | 54 | 58 | 108 | |

Note. [1]) and [2]): Observations failing for 1 and 2 months respectively.

**Table 49.**

und (26 m.), and means of surface temperature at Skagens Rev, Schultz Grund and Christiansø.

| Skagens Rev, 0 m. | | | Schultz Grund, 0 m. | | | | Christiansø, 0 m, | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th |
| 93 | 172 | 75 | 19 | 100 | 177 | 69 | 19 | 66 | 171 | 81 |
| 79 | 141 | 71 | — | 90[1]) | 150 | 66 | 10 | 55 | 137 | 74 |
| 103 | 173 | 76 | 35 | 102 | 167 | 67 | 38 | 81 | 161 | 88 |
| 94 | 165 | 89 | 11 | 91 | 161 | 78 | 21 | 71 | 155 | 82 |
| 93 | 172 | 86 | 28 | 95 | 173 | 78 | 33 | 73 | 171 | 81 |
| 89 | 150 | 74 | 17 | 91 | 159 | 64 | 24 | 68 | 155 | 82 |
| 89 | 154 | 84 | 11 | 99 | 162 | 84 | 25 | — | — | — |
| 87 | 147 | 66 | 16 | 90 | 158 | 70 | — | — | — | — |
| 61[1]) | 139 | 72 | 2[2]) | 67[1]) | 150 | 71 | — | — | — | — |
| 105 | 151 | 76 | 9[1]) | 112 | 162 | 74 | 18 | 77 | 152 | 80 |
| 90 | 144 | 69 | 22 | 100 | 154 | 68 | 30 | 72 | 157 | 78 |
| 87 | 157 | 84 | 9[1]) | 86 | 161 | 84 | 18 | 63 | 156 | 95 |
| 84 | 146 | 79 | 10 | 91 | 154 | 71 | 22 | 67 | 153 | 85 |
| 94 | 158 | 81 | 3 | 98 | 167 | 74 | — | — | — | — |
| 98 | 158 | 77 | 22 | 105 | 162 | 76 | — | — | — | — |
| 93 | 154 | 79 | 5[2]) | 100 | 161 | 73 | — | — | — | — |
| 106 | 161 | 76 | 18 | 109 | 167 | 70 | — | — | — | — |
| 93 | 163 | 85 | 8[1]) | 100 | 166 | 78 | — | — | 160 | 79 |
| 85 | 143 | 85 | 30 | 86 | 148 | 81 | 30 | 69 | 142 | 89 |
| 87 | 160 | 81 | 26 | 92 | 167 | 77 | 31 | 67 | 163 | 82 |
| 82 | 155 | 85 | 7 | 87 | 164 | 81 | 19 | 64 | 161 | 84 |
| 93 | 167 | 85 | 10 | 92 | 171 | 80 | 24 | 69 | 173 | 86 |
| 80 | 135 | 66 | 16 | 86 | 143 | 60 | 24 | 65 | 140 | 74 |
| 94 | 145 | 77 | 25 | 94 | 151 | 69 | 28 | 77 | 143 | 74 |
| 83 | 151 | 87 | 14 | 92 | 155 | 80 | 26 | 73 | 152 | 90 |
| 91 | 155 | 70 | 19 | 92 | 163 | 65 | 27 | 74 | 155 | 73 |
| 97 | 152 | 87 | 18 | 100 | 163 | 80 | 26 | 79 | 154 | 88 |
| 83 | 138 | 89 | 12 | 84 | 142 | 88 | 20 | 54 | 131 | 94 |
| 86 | 158 | 79 | 23 | 88 | 163 | 73 | 22 | 59 | 159 | 82 |
| 74 | 142 | 86 | 6 | 78 | 150 | 82 | 14 | 51 | 137 | 89 |
| 101 | 162 | 80 | 27 | 102 | 164 | 77 | 32 | 71 | 155 | 93 |
| 100 | 163 | 84 | 27 | 98 | 167 | 81 | 30 | 73 | 161 | 90 |
| 91 | 158 | 78 | 12[1]) | 91 | 158 | 70 | 24 | 72 | 158 | 75 |
| 96 | 158 | 93 | 22 | 95 | 162 | 85 | 32 | 76 | 155 | 101 |
| 101 | 170 | 78 | 24 | 102 | 178 | 77 | 35 | 81 | 173 | 84 |
| 84 | 150 | 61 | 14 | 88 | 156 | 62 | 25 | 64 | 149 | 75 |
| 83 | 148 | 79 | 17 | 88 | 158 | 74 | 22 | 62 | 140 | 84 |
| 81 | 161 | 81 | 7[1]) | 91 | 169 | 78 | 18 | 60 | 158 | 77 |
| 91 | 148 | 87 | 10 | 96 | 155 | 80 | 18 | 65 | 148 | 85 |
| 91 | 146 | 63 | 20 | 97 | 151 | 59 | 28 | 71 | 141 | 69 |
| 98 | 151 | 75 | 18 | 100 | 156 | 67 | 22 | 77 | 155 | 82 |
| 104 | 142 | 78 | 31 | 110 | 153 | 71 | 33 | 91 | 150 | 83 |
| 78 | 143 | 74 | 16[1]) | 86 | 148 | 67 | 12 | 63 | 138 | 66 |
| 73 | 141 | 74 | 21 | 79 | 146 | 73 | 22 | 52 | 133 | 72 |
| 72 | 150 | 91 | 1[2]) | 77 | 154 | 82 | 2 | 44 | 142 | 89 |
| 98 | 163 | 68 | 36 | 105 | 165 | 64 | 39 | 80 | 161 | 73 |
| 96 | 165 | 81 | 17 | 99 | 167 | 78 | 19 | 70 | 162 | 81 |
| 82 | 162 | 65 | 31 | 85 | 164 | 65 | 30 | 62 | 155 | 66 |
| 84 | 142 | 88 | 14 | 87 | 149 | 81 | 17 | 53 | 137 | 85 |
| 77 | 146 | 90 | 2[2]) | 80 | 152 | 85 | 10 | 44 | 143 | 89 |
| 100 | 161 | 90 | 25 | 105 | 163 | 81 | 35 | 80 | 158 | 89 |
| 80 | 146 | 80 | 12 | 87 | 153 | 73 | 17 | 53 | 136 | 76 |
| 92 | 166 | 83 | 20 | 95 | 175 | 79 | 23 | 64 | 167 | 79 |
| 103 | 166 | 75 | 18 | 105 | 171 | 77 | 25 | 75 | 165 | 84 |
| 92 | 165 | 97 | 31 | 101 | 171 | 92 | 30 | 83 | 168 | 96 |

II.

# ÜBER ALS "FREMDLINGE" ZU BEZEICHNENDE GROSSPLANKTONTEN IN DER OSTSEE.

VON

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## Einleitung.

UNTER Grossplanktontonten verstehen wir, wie der Name schon andeutet, die grösseren Planktontiere (Pflanzen kommen hierbei ht in Frage), etwa von der Grösse der kleinen dusen, Fischeier oder grösseren Copepoden auf- rts.

Die im folgenden mitgeteilten Tatsachen grün- sich im wesentlichen auf den Beobachtungen, auf den 5 nach dem Weltkriege ausgeführten seefahrten des Reichsforschungsdampfers "Po- lon" gewonnen wurden. Diese Fahrten fanden er Leitung von Direktor Dr. Strodtmann t: April 1925, Juli 1926, April 1929, Mai—Juni 1 und März—April 1933. Die Planktonunter- hungen wurden 1925 und 1926 von dem ver- rbenen Direktor der Biologischen Anstalt auf goland, Professor Mielck, 1929 vom Ver- er und 1931 sowie 1933 von beiden gemeinsam geführt. Die Fahrten erstreckten sich von der ler Bucht bis zum Danziger Becken oder bis in gotländischen Gewässer.

Die mit den verschiedensten Planktonnetzen aus- führten Fänge konnten wegen Mangel an Zeit Arbeitskräften nicht alle gründlich bearbeitet den. Dieses liess sich nur bei dem Material von 1 und 1933 ermöglichen, z. T. auch bei dem von 5. Die Fänge von 1926 und 1929 wurden bzgl. ossplankton lediglich an Bord einer kurzen rchsicht unterzogen, bei der aber jedenfalls entliche Bestandteile des Planktons nicht über- en wurden. Immerhin muss betont werden, dass folgenden Ausführungen nur ein vorläufiges räge tragen können, vor allem auch, weil die l der Beobachtungen nur verhältnismässig ge- g ist. Das gilt besonders auch hinsichtlich der gefügten Tabelle. Unsere Kenntnisse der Gross- nkton-Bevölkerung der Ostsee sind noch nicht eit gediehen, dass wir bei allen Formen die enart ihres Vorkommens im Gebiet mit voll- mmener Sicherheit beurteilen könnten.

Die Angaben in der Literatur über das Gross- nkton der Ostsee sind wenig umfangreich, da in heren Jahren den grösseren Planktonten dieses wässers wenig Beachtung geschenkt wurde. Wo diesbezügliche Bemerkungen fanden, sind sie wertet worden.

## Was sind "Fremdlinge"?

Heincke (2) bezeichnet als ganz seltene Arten (Fische) solche, "die nur vereinzelt gefangen werden und sich im Gebiet nicht fortpflanzen". Er bemerkt, dass sich scharfe Grenzen zwischen dieser Gruppe und seinen zwei übrigen (häufige Standfische und seltene Standfische) nicht ziehen lassen. Hesse (3) gebraucht den Ausdruck Gäste oder Irrlinge für heterotope Tiere, die als mehr oder weniger zufällige Vorkommnisse im fremden Biotop "eine Zeitlang darin leben, dann aber mit Sicherheit zugrunde gehen, wenn sie nicht den Weg wieder herausfinden in ihnen zusagendere Biotope".

Für Planktonten können wir diese Begriffsbestimmungen nicht oder nur bedingt anwenden. Die Verhältnisse liegen folgendermassen.

Das Auftreten eines Faunengastes setzt immer sein Herkommen aus einer anderen Fauna und damit aus einem anderen Gebiet voraus. Analog verhält sich, wenn wir die Begriffe enger fassen, ein Biotopgast. Der Gast muss also, um ein solcher zu werden, seinen Ort verändert haben. Bekanntlich handelt es sich bei den über grössere Strecken hin erfolgenden Ortsveränderungen der Planktonten nicht um aktive Wanderungen sondern um eine passive Verfrachtung durch die Wasserströmung. Bei dem geographisch-hydrographisch bedingten Strömen des Wassers werden ganze Wassermassen verschoben und in diesen Wassermassen die darin enthaltenen Planktonten. Während also sonst bei den Tieren, die wir als Gäste bezeichnen, das Einzelindividuum oder eine meist doch beschränkte Anzahl von Individuen aus der Fauna, zu der sie ursprünglich gehörten, und aus ihrem natürlichen Biotop heraus in fremde Umgebung gelangen, bewegt sich bei den Planktonten, wie man wohl sagen kann, der ganze Lebensraum samt seiner ganzen in ihm befindlichen Planktongemeinschaft[1]).

Die Angehörigen dieser mit ihrem Lebensraum fortbewegten Gemeinschaften können wir nicht ohne weiteres als Gäste bezeichnen, wenn sie in andere

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[1]) Die Fälle, in denen *einzelne* Planktonten passiv verschleppt werden, bleiben unberücksichtigt, weil sie in unserem Gebiet noch nicht nachgewiesen wurden.

Gebiete gelangen. Nun verliert aber die fortbewegte Wassermasse, die Strömung, im Verlauf ihrer Wanderung irgendwann und irgendwo ihre ursprüngliche Eigenart als der betreffende Lebensraum. Das geschieht durch äussere geographisch bedingte Einflüsse und durch Mischung mit anderen Wassermassen. Dann ist es so, dass die überwiegende Mehrzahl der anfangs in der Wassermasse vorhandenen Planktonten — von ganz euryöken Formen abgesehen — keine ausreichenden Lebensbedingungen mehr findet und abstirbt, die eine Art früher, die andere später. Sie werden ersetzt durch Formen, die in dem veränderten Wasser gedeihen können, für die also dieses der zusagende Lebensraum ist. Die Reste der ursprünglichen Planktongemeinschaft, die sich in einer Überzahl in dem andersartigen Wasser heimischer Arten finden, könnte man als Gäste bezeichnen, wenn auch dieser Ausdruck hier nicht recht am Platze ist. Um das Wort Gäste, das in der Biogeographie einen ganz bestimmten Klang hat, zu vermeiden, wählen wir vielleicht lieber die Bezeichnung Fremdlinge, weil die fraglichen Formen in ihrer Umwelt fremd erscheinen. Oft ist es dann so, dass diese übrig gebliebenen Planktonten wohl noch leben aber sich nicht mehr fortpflanzen können, was an die oben genannte Definition von H e i n c k e anschliesst.

Aus dem eben Gesagten ergibt sich, mit welchen Planktonten wir uns fernerhin beschäftigen wollen. Dass die Abgrenzung gegen die "einheimischen" Arten unscharf ist, bedarf keiner besonderen Betonung. Die speziellen Besonderheiten unseres Gebietes werden unten zur Sprache kommen.

## Die hydrographischen Verhältnisse.

Die hydrographischen Verhältnisse bedingen einen scharfen Unterschied zwischen der westlichen Ostsee einerseits und der mittleren und östlichen Ostsee andererseits.

Die westliche Ostsee umfasst die Kieler und Mecklenburger Bucht im weiteren Sinne und wird im Osten durch das Gebiet zwischen Rügen und Möen abgeschlossen. Durch den Grossen Belt[1]) geht ein bald schwächerer, bald stärkerer salzreicher Tiefenstrom aus dem Kattegat in die westliche Ostsee hinein; sie ist demzufolge der Teil, welcher in der Tiefe die Eigenschaften des offenen Meeres am stärksten ausgeprägt besitzt. An der Oberfläche macht sich ein nach dem Kattegat ausgehender, von Osten kommender Oberflächenstrom bemerkbar, der in Ostwindperioden stärker zu sein pflegt als sonst. Der Tiefensalzgehalt kann an manchen Stellen und zu gewissen Zeiten an 30 $^0/_{00}$ betragen, während er an der Oberfläche bis unter 8 $^0/_{00}$ sinken kann.

Das Flachgebiet westlich und nordwestlich von Rügen, vor allem der zwischen Darss und Gjed verlaufende unterseeische Rücken, die Darss Schwelle, verwehrt dem salzreichen Tiefenwass für gewöhnlich den Durchtritt nach Osten in d mittlere Ostsee hinein. Hier findet sich höher Salzgehalt nur in den Tiefen der Becken, Arkon Bornholm- usw. Becken. Darüber liegt ei schwach salzige Oberschicht von $< 8\,^0/_{00}$ Sa gehalt, welche die flacheren Gebiete bis zum Grun erfüllt. Das salzigere Tiefenwasser ist in den Beck im allgemeinen isoliert, ganz mit schwach salzige Wasser erfüllte Gebiete trennen die Becken von ei ander. Das Tiefenwasser in den Becken stagnie und hat einen mehr oder weniger stark vermi derten Sauerstoffgehalt.

Nur zu gewissen Zeiten, wenn der Zustrom sal reichen Wassers aus dem Kattegat besonders sta ist, dringt in der Tiefe neues Wasser von der we lichen in die mittlere Ostsee hinein und strömt das Arkona- und Bornholm-Becken und vielleic noch weiter nach Osten. Dann findet sich in de Becken in den tieferen Schichten Wasser vo höherem Salz- und vor allem höheren Sauerstof gehalt als sonst.

Eine solche Periode des Einstroms neuen Wa sers trafen wir auf der "Poseidon"-Fahrt im Apr 1933, wo nach den Beobachtungen der Deutsche Seewarte der Tiefensalzgehalt im Bornholm-Becke auf die gewöhnlich nicht erreichte Höhe von üb 16 $^0/_{00}$ stieg.

Diese kurzen Hinweise auf die hydrograph schen Verhältnisse müssen hier genügen; Nähere bei S c h u l z (Die Tierwelt der Nord- und Ostse hrsg. von G. G r i m p e, Teil I $d_2$, 1932).

## Die "Fremdlinge" in der Ostsee.

### a. Westliche Ostsee.

Das salzreiche Tiefenwasser der westlichen Os see stammt, wie im vorhergehenden Abschnitt ge sagt, aus dem Kattegat und wird von dort dauern ergänzt. Das einströmende Wasser führt Plankto ten aus dem Kattegat herein, Arten, die dort un weiterhin auch in der Nordsee vorkommen. Die Formen sind in der westlichen Ostsee mehr ode weniger regelmässig und in grösserer oder geri gerer Individuenzahl anzutreffen. Z. T. vermöge sie sich hier auch noch fortzupflanzen. Wir dürfe sie nicht eigentlich als Fremdlinge bezeichnen. E können hier nur Beispiele solcher Arten angeführ werden (vgl. Tabelle): Von Anthomedusen *Hybo codon prolifer* und *Rathkea octopunctata;* vo Leptomedusen *Eutonina indicans;* die Ctenophor *Bolina infundibulum;* der Copepode *Calanus fin marchicus;* vielleicht die Mysidee *Mesopodopsi (Macropsis) slabberi;* der Chaetognath *Sagitt setosa.* Diese und noch andere Arten sind in de Ostsee auf den westlichen Teil beschränkt, wen nicht die später zu besprechenden aussergewöhn lichen Verhältnisse vorliegen. Zwischen diesen Ar ten finden sich — aber nicht in Überzahl —

[1]) Sund und Kleiner Belt kommen wegen ihrer geringen Tiefe für den Einstrom kaum oder garnicht in Betracht.

e, die entweder sowohl im offenen Meere wie in der Ostsee weit verbreitet sind, als Beispiele cyphomedusen *Cyanea capillata* und *Aurelia* und die Ctenophore *Pleurobrachia pileus;* solche, die (in unserer Zone) auf die Ostsee ränkt sind, in ihr aber bis weit nach Osten mmen, wie die Anthomeduse *Halitholus us.*

usser den anfangs genannten Arten treffen wir in der westlichen Ostsee auch solche, die wir ehr Recht als Fremdlinge bezeichnen könnten, ch die, welche wahrscheinlich nicht immer in erer Zahl in das Gebiet gelangen, sondern nur erscheinen, wenn der Einstrom etwas stärker Hierher gehören u. a. die Trachymeduse *tha digitalis,* vielleicht die Ctenophore *Beroë uis,* ferner der Euphauside *Nyctiphanes couchi* er Pteropode *Limacina retroversa* (1, 7). Wie diesen Arten mit der Fortpflanzungsfähigkeit ebiet ist, wissen wir nicht sicher.

arüber hinaus können wir noch eine dritte e hereingetriebener Planktonten abgrenzen, ch die Arten, welche sicher nur ausnahms- erscheinen, wenn der Einstrom besonders ist. Wir nennen hier Siphonophoren bzw. Reste (Artzugehörigkeit nicht bestimmt), die omeduse *Rhizostoma octopus* (7) und den oden *Calanus hyperboreus* (6). Diese Arten wirklich als Fremdlinge zu betrachten. Sie en sich im Gebiet höchstwahrscheinlich nicht

das Auftreten dieser Gruppe schliesst sich nteressante Erscheinen von für die westliche fremdartiger Fischbrut an. Sehr bekannt den ist das Eindringen von Schellfischlarven *s aeglefinus),* das im Frühjahr 1923 erfolgte. zeitig kamen auch noch andere fremde Fisch-, z. B. von *Gadus virens* und *Anarrhichas* sowie Siphonophoren usw. (4). Hier liegt achtenswerte Fall vor, dass Naturerscheinun- ie zunächst für den Menschen ganz belanglos einen, plötzlich eine grosse Bedeutung für den- gewinnen. Denn auf diesem Auftreten der fischlarven in der Ostsee gründete sich ja n den folgenden Jahren so einträgliche erei nach den erwachsenen Tieren.

ehr lässt sich bis jetzt über die Verhältnisse r westlichen Ostsee nicht sagen. Nur ein- de re, über längere Zeiträume ausgedehnte chtungen können uns weiterbringen.

**e mittlere Ostsee.**

er Fremdlinge in der Planktonfauna der ganz chwach salzigem Wasser erfüllten Flachgebiete sich bis jetzt nichts aussagen. In den Fluss- ungsgebieten können Süsswasserformen, die nicht zum Grossplankton gehören, ziemlich weit in die (vor den Flüssen besonders stark ausgesüsste) See gelangen und vielleicht als Fremdlinge auftreten.

Interessante Verhältnisse können aber in den Becken der mittleren Ostsee, Arkona- und Bornholm-Becken, zur Beobachtung kommen.

Wie erwähnt, strömt von Zeit zu Zeit neues salzreiches Wasser von Westen her in diese Becken. So können westliche Planktonten in diese Becken gelangen, die hier für gewöhnlich nicht gefunden werden. Diese Formen sterben nach Massgabe ihrer Widerstandsfähigkeit gegenüber den Veränderungen, die das eingeströmte Wasser mit der Zeit erleidet, früher oder später aus.

Während der "Poseidon"-Fahrt im April 1933 trafen wir eine solche Periode frischen Einstromes an (6). Wir fanden folgende westliche Arten: die Anthomedusen *Sarsia tubulosa*[1]), *Hybocodon prolifer* und *Rathkea octopunctata, Larven* von *Eupagurus bernhardus* und ferner *Sagitta setosa.* Das frisch eingedrungene Wasser hatte sich aber — mindestens teilweise — schon mit dem seit längerer Zeit vorhandenen Wasser vermischt, sodass sich zwischen den neu angekommenen Planktonten auch an Ort und Stelle heimische fanden, z. B. *Sagitta elegans baltica.*

Im Mai—Juni 1931 war nichts von einem jüngst stattgehabten Einstrom zu spüren. Wir fanden aber trotzdem die Reste einer wahrscheinlich schon vor längerer Zeit eingeführten Planktonfauna, nämlich ausser *Sarsia tubulosa* (Arkona-Becken) die Leptomeduse *Melicertum octocostatum* und ferner *Calanus finmarchicus* (6).

Aus den mitgeteilten Beobachtungen geht hervor, dass wir in den Becken der mittleren Ostsee unter Umständen Planktonten finden können, die in der westlichen Ostsee vielleicht gewöhnliche Erscheinungen, weiter östlich aber durchaus als Fremdlinge zu betrachten sind.

**c. Östliche und nördliche Ostsee.**

Wie es hier mit dem Auftreten von Fremdlingen bestellt ist, kann nicht gesagt werden, da diesbezügliche sichere Angaben nicht gefunden wurden. Die marinen Planktonten müssen in diesen Teilen der Ostsee die Ost- bzw. Nordgrenze ihres Vorkommens erreichen und zwar dort, wo der Salzgehalt des Wassers zu gering wird, bzw. das Salzwasser in Süsswasser übergeht. Es ist denkbar, dass an diesen Grenzen Planktonten durch ungewöhnliche Strömungsverhältnisse, die durch besondere Winde hervorgerufen werden, in Gebiete zu gelangen vermögen, in denen sie gewöhnlich fehlen. So könnten Fremdlinge in Erscheinung treten.

[1]) *S. tubulosa* wird im Arkona-Becken verhältnismässig oft, in Bornholm-Becken aber nur ausnahmsweise angetroffen.

## Westliche Ostsee (Kieler und Mecklenburger Bucht).

| regelmässig vorkommend<br>gespert: in der Ostsee weiter verbreitete Arten | Fremdlinge |
|---|---|
| Anthomedusae<br>Sarsia tubulosa<br>Hybocodon prolifer<br>Rathkea octopunctata<br>Halitholus cirratus | Anthomedusae<br>Steenstrupia nutans (5)<br>Euphysa aurata (5, 7)<br>Euphysa tentaculata (5, 6)<br>Purena gemmifera (5)<br>Bougainvillia superciliaris (5) |
| Leptomedusae<br>Eutonina indicans<br>Obelia | Leptomedusae<br>Phialidium hemisphaericum (7)<br>Eucopium quadratum (7)<br>Melicertum octocostatum (7)<br>Tima bairdi "Poseidon" 1935 |
| Scyphomedusae<br>Cyanea capillata<br>Aurelia aurita | Trachymedusae<br>Aglantha digitalis (6) |
| Ctenophorae<br>Pleurobrachia pileus<br>Bolina infundibulum | Siphonophorae (1) u. "Poseidon" 1926 |
| Vermes<br>Harmothoë sarsi<br>Sacconereis | Scyphomedusae<br>Rhizostoma octopus (7) |
| Copepoda<br>Calanus finmarchicus<br>Limnocalanus grimaldi | Ctenophorae<br>Beroë cucumis (6) |
| Mysidacea<br>Gastrosaccus spinifer<br>Mesopodopsis slabberi<br>Praunus inermis<br>Praunus flexuosus<br>Mysis mixta<br>Neomysis vulgaris<br>Paramysis ornata (+ kervillei?) (8)<br>Paramysis spiritus | Copepoda<br>Calanus hyperboreus (6) |
| | Euphausiacea<br>Nyctiphanes couchi (6) |
| | Mysidacea<br>?Gastrosaccus sanctus (7) |
| Decapoda Larvae<br>Leander adspersus var. fabricii<br>Eupagurus bernhardus<br>Carcinus maenas<br>u. andere | Pteropoda<br>Limacina retroversa (1, 7) |
| Chaetognatha<br>Sagitta setosa<br>Sagitta elegans elegans | |

## Mittlere Ostsee (Rügen bis Gotland).

| regelmässig vorkommend | Fremdlinge im Arkona- und Bornholm-Becken |
|---|---|
| omedusae<br>Halitholus cirratus<br>homedusae<br>Cyanea capillata<br>Aurelia aurita<br>phorae<br>Pleurobrachia pileus<br>poda<br>Limnocalanus grimaldi<br>lacea<br>Gastrosaccus spinifer<br>Praunus inermis<br>Praunus flexuosus<br>Mysis mixta<br>Mysis relicta (erst ab Bornholm-Becken, nur Tiefe)<br>Neomysis vulgaris<br>ipoda<br>Hyperia galba<br>ognatha<br>Sagitta elegans baltica (nur Tiefe) | Anthomedusae<br>Sarsia tubulosa (6)<br>Hybocodon prolifer (6)<br>Rathkea octopunctata (6)<br>?Catablema vesicarium (1)<br>Leptomedusae<br>Melicertum octocostatum (6)<br>Copepoda<br>Calanus finmarchicus (6)<br>Decapoda Larvae<br>Eupagurus bernhardus (6)<br>Pteropoda<br>Limacina retroversa (1)<br>Chaetognatha<br>Sagitta setosa (6) |

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III.

# FLUCTUATIONS IN THE REGIONAL DISTRIBUTION OF CERTAIN SH-STOCKS WITHIN THE TRANSITION AREA DURING RECENT YEARS (1923–1935).

BY

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(MS. received Dec. 1935.)

URING recent years it has been repeatedly observed that fish which normally advance no farther towards the brackish water of Baltic than to the northern parts of the ition Area have made their way unusually far wards into this sea area, not only as isolated mens, but in such large numbers that we are ied in speaking of a real — if only temporary tension of the regional distribution of these s in a southerly direction, that is to say, ds the brackish water of the Baltic.

uch a temporary expansion in a southerly ion of the area of distribution of some species h was first observed and examined in 1923 . Johansen (6—7), C. G. Joh. Peter- 11) and H. Heidrich (4)]. An unusually unced inflow of salt water in spring and early er carried large quantities of haddock larvae the northern Kattegat into the southern parts e Transition Area, where they grew up during llowing years and became the object of an ive fishery during the winter of 1925—26. , in the spring of 1926, their first maturity d, most of these haddock emigrated from the At the same time a few spent haddock were t in the western Baltic, but investigations d out in those waters failed to establish the nce of larvae, and it must therefore be ed that the eggs spawned in this locality did evelop.

similar, though considerably smaller, inflow ddock larvae into the Belt Sea was observed e early summer of 1928, again in connexion a strong inflow of salt water (12).

similar inflow of larvae of another fish of od family, the saithe or coalfish *(Gadus )* was also observed (13); in the ring-trawl y at the end of April, 1932, considerable it es of saithe larvae were found throughout astern Kattegat, and in the summer of the year the bottom stages of the 0-group were in large numbers throughout the Kattegat he northern parts of the Sound and the Belt The larvae thrived excellently and in the ving years, 1933 and 1934, numbers of saithe d II-group) were caught in the Kattegat, the l and the northern Belt Sea. A few specimens taken even so far to the southwards as off und in the southern part of the Little Belt.

Shoals, not only of larvae, but also of older fish, advanced far into the Transition Area during the period under review. In November and December, 1933, considerable quantities of anchovy *(Engraulis encrasicholus)* were taken in the western Baltic [P. Fr. Meyer (8)]; mackerel *(Scomber scomber)* were caught in extraordinary numbers off the Polish coast in 1928 and 1929 (according to information conveyed by letter by Professor M. Siedlecki); also German fishermen are reported to have landed unusually heavy catches of long rough dab *(Drepanopsetta platessoides)* from the western Baltic in the years 1932/34 (3).

In connexion with these more sporadic observations of an unusually marked inroad of some few species of fish southwards into the Transition Area the question naturally arises whether other species of fish have moved in a southerly direction beyond their normal limits during this period, or in other words whether, during these years, the fish-stocks of these areas have shown a general tendency to make a temporary expansion southwards of the regional distribution of the species. The following is an attempt to answer this question on the basis of fishery investigations carried out by the Danish Biological Station and by the Danish Commission for Fishery and Marine Research during the series of years under consideration. The material utilised here was collected in experimental hauls, partly for larvae with the ring-trawl, partly for older fish (from the bottom stages of the 0-group upwards) with the eel-tog or the otter seine.

In the main the present investigation includes only such species of fish as will normally occur in the northern part of the Transition Area, or at any rate in the parts of the North Sea adjoining the Transition Area. No regard has been paid to species which are mere "visitors" within the area, such as *Brama rayi*, *Centrolophus*, etc. Furthermore, the investigation comprises chiefly only species whose occurrence is comparatively frequent in the catches of the experimental hauls, so that the fish fauna of the shallow water, the typical species of the Zostera and the Fucus bottom, are omitted.

In such investigation, however, the difficulty will always arise of fixing the southern limit of the

## Table 1.

Number of Larvae of *Drepanopsetta platessoides*, *Gadus merlangus*, *G. æglefinus*, *G. virens*, *G. minutus*, *G. esma* and *G. pollachius* caught pr. 30 Minutes in a two Metres Ring Trawl in the Danish Waters within Skaw during the period 1904—35. (The first column gives the Number of Stations.)

| Year Month | No. of stat. | | | | *Drep. plat.* | | | | *Gad. merl.* | | | | *Gad. æglefin.* | | | | Other species | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Katte-gat | Belt Sea | West. Baltic | Baltic proper | Katte-gat | Belt Sea | West. Baltic | Baltic proper | Katte-gat | Belt Sea | West. Baltic | Baltic proper | Katte-gat | Belt Sea | West. Baltic | Baltic proper | Kattegat | Belt Sea |
| **1904** | | | | | | | | | | | | | | | | | | |
| Apr. | 7 | 3 | .. | .. | 4 | 9 | .. | .. | 0 | 0 | .. | .. | 0 | 0 | .. | .. | | |
| May | 5 | 11 | 2 | .. | 6 | 2 | 6 | .. | 1 | 0 | 0 | .. | 1 | 0 | 0 | .. | | |
| June | 6 | 9 | 5 | 5 | 10 | 0.3 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| **1907** | | | | | | | | | | | | | | | | | | |
| Apr. | 6 | .. | .. | .. | 0 | .. | .. | .. | 0 | .. | .. | .. | 0 | .. | .. | .. | | |
| May | 20 | .. | .. | .. | 2 | .. | .. | .. | 0.1 | .. | .. | .. | 0.1 | .. | .. | .. | | |
| June | 4 | .. | .. | .. | 1 | .. | .. | .. | 0 | .. | .. | .. | 0 | .. | .. | .. | | |
| **1908** | | | | | | | | | | | | | | | | | | |
| Apr. | 6[1] | 1 | 1 | 1 | 7 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | [1] 0.1 *G. es.* | |
| May | .. | .. | 6 | 1 | .. | .. | 0 | 0 | .. | .. | 0 | 0 | .. | .. | 0 | 0 | | |
| **1911** | | | | | | | | | | | | | | | | | | |
| May | 10 | 4 | 3 | .. | 2 | 0 | 0 | .. | 1 | 0 | 0 | .. | 0 | 0 | 0 | .. | | |
| June | 14 | .. | .. | .. | 0 | .. | .. | .. | 19 | .. | .. | .. | 0 | .. | .. | .. | | |
| **1923** | | | | | | | | | | | | | | | | | | |
| Apr. | 22[1] | 5 | 12 | 5 | 15 | 2 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | [1] 0.1 *G. es.* | |
| May | 12[1] | 9[2] | .. | .. | 146 | 60 | .. | .. | 12 | 10 | .. | .. | 13 | 0.2 | .. | .. | [1] 1. *G. es.* 1. *G. p.* | [2] 0.1 *G.* |
| June | .. | 4 | 10 | 37 | .. | 5 | 6 | 0.4 | .. | 2 | 4 | 0.1 | .. | 0 | 1 | 0 | | |
| **1924** | | | | | | | | | | | | | | | | | | |
| Apr. | 5 | 2 | .. | .. | 0 | 0 | .. | .. | 0 | 0 | .. | .. | 0 | 0 | .. | .. | | |
| **1925** | | | | | | | | | | | | | | | | | | |
| Apr. | 20[1] | 7 | 5 | 9 | 2 | 0.3 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | [1] 0.1 *G. es.* | |
| **1926** | | | | | | | | | | | | | | | | | | |
| Apr. | 11 | .. | .. | .. | 17 | .. | .. | .. | 0.1 | .. | .. | .. | 0 | .. | .. | .. | | |
| May | 10 | 10 | 7 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | | |
| **1927** | | | | | | | | | | | | | | | | | | |
| Mar. | 1 | 23 | 1 | .. | 0 | 0 | 0 | .. | 0 | 0 | 0 | .. | 0 | 0 | 0 | .. | | |
| Apr. | 3 | 15 | 3 | .. | 0 | 0.4 | 0.3 | .. | 0 | 0 | 0 | .. | 1 | 0 | 0 | .. | | |
| May | 5[1] | 2 | .. | .. | 1 | 2 | .. | .. | 4 | 0 | .. | .. | 0 | 0 | .. | .. | [1] 0.2 *G. p.* | |
| **1928** | | | | | | | | | | | | | | | | | | |
| May | .. | 7 | .. | .. | .. | 0 | .. | .. | .. | 0 | .. | .. | .. | 0.4 | .. | .. | | |
| June | 4 | 14 | 3 | .. | 5 | 0.2 | 0 | .. | 38 | 0.1 | 0 | .. | 0.3 | 0.3 | 0 | .. | | |
| **1929** | | | | | | | | | | | | | | | | | | |
| Apr. | 9 | 16 | 4 | .. | 5 | 0.5 | 0 | .. | 0 | 0 | 0 | .. | 0.1 | .. | .. | .. | | |
| May | 21 | 40 | 13 | .. | 29 | 3 | 0 | .. | 0.7 | 0.3 | 0 | .. | 2 | 0.3 | 0.2 | .. | | |
| June | .. | 14 | .. | .. | .. | 2 | .. | .. | .. | 0 | .. | .. | .. | 0 | .. | .. | | |
| **1930** | | | | | | | | | | | | | | | | | | |
| Apr. | 24[1] | 40 | 5 | 6 | 12 | 2 | 0 | 0 | 3 | 0.1 | 0 | 0 | 0.3 | 0 | 0 | 0 | [1] 0.2 *G. p.* | |
| May | 25[1] | 18 | .. | .. | 10 | 3 | .. | .. | 1 | 0.4 | .. | .. | 0.4 | 0 | .. | .. | [1] 0.1 *G. p.* | |
| June | .. | 28[1] | 9 | .. | .. | 0.1 | 0 | .. | .. | 0.2 | 0 | .. | .. | 0 | 0 | .. | | [1] 0.1 *G.* |
| **1931** | | | | | | | | | | | | | | | | | | |
| Apr. | 6 | 26 | 4 | .. | 6 | 1 | 0 | .. | 0 | 0 | 0 | .. | 0 | 0 | 0 | .. | | |
| May | .. | 1 | .. | .. | .. | 0 | .. | .. | .. | 0 | .. | .. | .. | 0 | .. | .. | | |
| June | 3 | .. | .. | .. | 0 | .. | .. | .. | 1 | .. | .. | .. | 0 | .. | .. | .. | | |
| **1932** | | | | | | | | | | | | | | | | | | |
| Apr. | 14[1] | 17 | 4 | 13 | 6 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | [1] 0.5 *G. es.* 6 *G. vir.* | |
| May | 9 | .. | .. | .. | 8 | . | .. | .. | 2 | .. | .. | .. | 1 | .. | .. | .. | 5 *G. m.* | |
| **1933** | | | | | | | | | | | | | | | | | | |
| Apr. | 11 | 9 | .. | 11 | 2 | 1 | .. | .. | 0 | 0 | .. | 0 | 0 | 0 | .. | 0 | | |
| May | 6 | 2 | 6 | .. | 5 | 0.2 | 0 | .. | 0 | 0 | 0 | .. | 1 | 0.2 | 0 | .. | | |
| **1934** | | | | | | | | | | | | | | | | | | |
| Apr. | 19 | 8 | .. | .. | 4 | 2 | .. | .. | 0.1 | 0 | .. | .. | 0 | 0 | .. | .. | | |
| May | 1 | 11[1] | 2 | .. | 0 | 1 | 1 | .. | 0 | 0.3 | 0 | .. | 0 | 0 | 0 | .. | | [1] 0.4 *G.* |
| **1935** | | | | | | | | | | | | | | | | | | |
| Apr. | 23[1] | 31 | 4 | 3 | 2 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [1] 0.1 *G. vir.* | |
| May | 2[1] | 6 | .. | 5 | 0 | 0.2 | .. | 0 | 2 | 0.5 | .. | 0 | 0 | 0 | .. | 0 | [1] 0.5 *G. p.* | |
| June | .. | 3 | .. | 4 | .. | 0 | .. | 0 | .. | 0 | .. | 0 | .. | 0 | .. | 0 | | |

nal" sphere of distribution of a given species furthermore, the possibility cannot be entirely ooked that certain observations of a "southerly" rrence during recent years may be due to the nually increasing intensity with which fishery tigations have been pursued in these waters.

## he long rough dab *(Drepanopsetta platessoides).*

ccording to C. V. Otterstrøm [1914 (10)] ong rough dab is quite common as far to the in the Transition Area as "in most of the Sea and the western Baltic", but is unknown e Baltic proper and the southern part of the d. A. C. Johansen, 1912, (5) summing bservations relating to the long rough dab in Belt Sea made up to that time, says that "it ns in the Belt Sea without being conspicuously rous in these waters, and it belongs to the es that decrease rapidly in frequency from the gat through the Belt Sea and towards the . Eggs of long rough dab may be found as stwards as off Gedser; there are, however, no rtant spawning grounds of the long rough dab e Belt Sea."

ggs and larvae of the rough dab are rare in outhern Belt Sea and the western Baltic. The gical investigations carried out in these waters g the years before the great war led only to a sporadic discoveries of larvae. In 1904 the of rough dab seem to have advanced ularly far southwards. In this year extensive g experiments with the young-fish-trawl were d out in these waters by the Danish Biological n. A few eggs [A. Otterstrøm, 1906 (9)] found as far southwards as the Gedser Reef f the larvae six specimens were found per our haul in the western Baltic in May and pecimens were taken per half-hour haul in estern Baltic and the westernmost part of the proper in June (see Table 1). In 1908 the s were: in April one larva per half-hour haul e Belt Sea and the western Baltic and in May ecimens in the western Baltic and none in the proper. But in the years 1903, 1905, 1906, 1909, 1911 and 1912 neither Danish nor ar investigators (Kramp, Strodtmann, e nbaum, Apstein, Heinen, Hensen) eggs or larvae in the southern part of the Sea or in the western Baltic, still less in the proper. In other words, 1904 and to a far legree 1908 are the only years of the period review here in which any considerable er of larvae appeared in the waters in on.

rom 1923 onwards there has been an un- n series of Danish investigations, so that we nabled to obtain a fairly good idea of the fluctuations in the quantities of larvae during these years (see Table 1 and Figure 1). It appears from the table that quite exceptional quantities of rough dab larvae appeared in the Belt Sea and the western Baltic in 1923 (even far more than in 1904, which was the richest year until then). Also in the western part of the Baltic proper — the waters between Kriegers Flak and the eastern coasts of

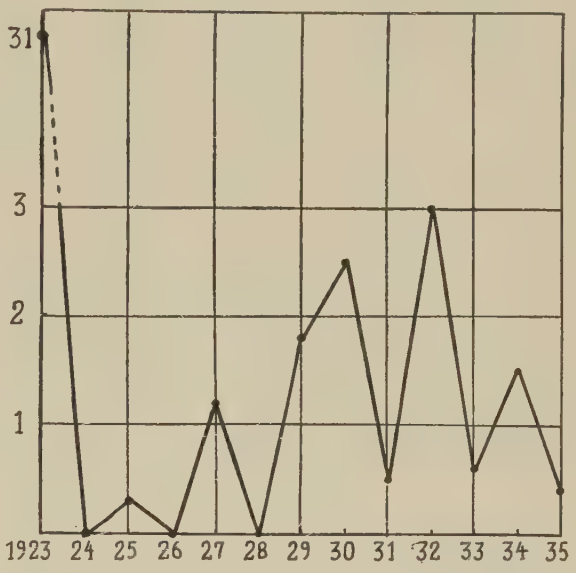


Fig. 1. Mean catch in the ring-trawl, per 30 minutes, of larvae of *Drepanopsetta platessoides* in the Belt Sea during April and May of the years 1923—35.

Møen and Falster — a few larvae of rough dab were taken in June of that year, a total of five specimens in 13 half-hour hauls. In the years 1924—26 and 1928 the catches of rough dab larvae were extremely small in the Belt Sea, less than 0.5 per half-hour; in 1927 somewhat higher. In the western Baltic the numbers were very small: in 1925, 1926 and 1928 none and in 1927 (in April) 0.3 individuals per half-hour (in 1924 there was no investigation). But from 1929 onwards the number of rough dab larvae in the Belts rises rapidly and is comparatively high in 1929, 1930 and 1932, but somewhat lower in 1931. In 1933 the number was again low. In 1934 there was a slight rise and in 1935 another fall. In the western Baltic during this period rough dab larvae were taken in one year only, viz. 1934. This negative result in the case of the western Baltic may, however, be due to the fact that only a few investigations were carried out in these waters.

As regards the rough dab the position may be briefly set out as follows: in the inner Danish waters the year 1923 was exceptionally rich in larvae and 1927, 1929, 1930, 1932 and 1934 were

**Table 2.**

**Length of Larvae of *Drepanopsetta platessoides* caught in different Danish Waters during the years 1**

| Area | Kattegat | | | North. Belt Sea | | | South. Belt Sea | | | West. Baltic | | | Baltic | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Apr. | May | June | Apr. | May | June | Apr. | May | June | Apr. | May | June | Apr. | M |
| 4 mm. | 7 | | | 7 | | | 1 | | | | | | | |
| 5 „ | 30 | 2 | | 20 | | | 2 | | | | | | | |
| 6 „ | 64 | 0 | | 30 | | | 5 | 1 | | | | | | |
| 7 „ | 104 | 6 | | 31 | 4 | | 6 | | | | | | | |
| 8 „ | 88 | 23 | | 36 | 1 | | 5 | 1 | | | | | | |
| 9 „ | 69 | 28 | | 25 | 8 | | 2 | | | | 2 | | | |
| 10 „ | 42 | 28 | | 15 | 7 | | | 1 | | 1 | | | | |
| 11 „ | 24 | 40 | | 8 | 5 | | | 4 | | | 2 | | | |
| 12 „ | 10 | 59 | | 3 | 8 | | | 3 | | | | | | |
| 13 „ | 3 | 56 | | 2 | 9 | | | 4 | | | | | | |
| 14 „ | 2 | 34 | | 1 | 6 | | | 2 | | | | | | |
| 15 „ | 1 | 20 | | 2 | 2 | | | | | | | 1 | | |
| 16 „ | | 21 | | | 7 | | | | | | | 1 | | |
| 17 „ | | 16 | | | 6 | | | 1 | | | | | | |
| 18 „ | | 8 | | | 4 | 1 | | | | | | 2 | | |
| 19 „ | | 7 | | | 5 | | | | | | | 1 | | |
| 20 „ | | 2 | | | 3 | 1 | | 1 | | | | | | |
| 21 „ | | 2 | | | 1 | | | 1 | | | | 1 | | |
| 22 „ | | 1 | | | 1 | | | | 1 | | | | | |
| 23 „ | | | | | | | | | | | | 1 | | |
| Total | 444 | 353 | | 180 | 77 | 2 | 21 | 19 | 1 | 1 | 4 | 7 | | |
| M. Length | 7.9 | 12.5 | | 7.7 | 13.6 | 19.0 | 6.9 | 12.7 | 22.0 | 10.0 | 10.0 | 18.6 | | |

comparatively rich; the intermediate years were poor in larvae.

Now the question arises whether these fluctuations of the numbers of larvae are due to a varying spawning intensity in combination with an extension of the spawning grounds in a southerly direction or whether they are caused by changes in the quantities of larvae introduced from without.

During the years under consideration spawners of long rough dab were rarely found in the southern Belt Sea or in the western Baltic. It is not until we get as far northwards as the deeper parts of the northern Belt Sea that we find a spawning stock of any importance. Examination of the lengths of the larvae shows similar conditions as to the situation of the spawning grounds (Table 2). In the Kattegat and in the northern part of the Belt Sea, to a lesser degree in the southern part, newly hatched larvae of 4 or 5 mm. in length were found in considerable numbers. In the western Baltic, on the other hand, the larvae found during the present investigation were at least 9 mm. long, in the Baltic proper at least 14 mm.; thus recently hatched larvae were not observed in these waters. From this fact the conclusion may be drawn that larvae found in these inner waters do not originate from a local spawning but have been introduced from without.

For the Belt Sea we have some age-analyses of rough dab caught in the eel-tog during recent years. The principal results of these analyses are given in the table below, which shows how many individ of the different year-classes were found in material examined (age-groups in brackets).

**Numbers of individuals.**

| | Investigated in: | | |
|---|---|---|---|
| | 1933 | 1934 | 193 |
| Year-class 1934 | | | 134 (I) |
| „ 1933 | | 73 (I) | 15 (II |
| „ 1932 | 301 (I) | 131 (II) | 51 (II |
| „ 1931 | 61 (II) | 22 (III) | 17 (IV |
| „ 1930 | 19 (III) | 8 (IV) | |
| „ 1929 | | 1 (V) | 1 (VI |
| „ 1928 | | 2 (VI) | |
| „ 1927 | | | 1 (V |

It appears that the results of the eel-tog fish are in good agreement with the larvae exami tions, which showed an abundance of larvae in years 1932 and 1934, the 1932 year-class be numerously represented in all three years: in 1 and 1934 it was the richest year-class and in 1 it was outnumbered only by the new rich ye class of 1934. For the western Baltic we have few age-determinations, but here, too, the 1 year-class was a rich one.

Though the age-analyses are few and sporac they so far corroborate the results of the lar investigations as to show that, once they h drifted in, the larvae will thrive and develop

**able 3. No. of *Drepanopsetta platessoides* caught in the Eel-tog pr. 30 min. in the years 1927—35 in the Belt Sea, the Western Baltic, and the Baltic proper.**

| | 1927 | | | 1928 | | | 1929 | | | 1930 | | | 1931 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. |
| Belt Sea .... | 42 | 291 | **6.9** | 87 | 545 | **6.3** | 44 | 402 | **9.1** | 65 | 385 | **5.9** | 91 | 878 | **9.8** |
| Western Baltic | 6 | 2 | **0.3** | 10 | 81 | **8.1** | 1 | 0 | **0** | 18 | 119 | **6.6** | 7 | 44 | **6.3** |
| Baltic proper. | 49 | 2 | **0.04** | 58 | 1 | **0.02** | 3 | 0 | **0** | 25 | 0 | **0** | 13 | 0 | **0** |

| | 1932 | | | 1933 | | | 1934 | | | 1935 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. |
| Belt Sea .... | 86 | 1130 | **13.1** | 41 | 700 | **17.1** | 55 | 257 | **4.7** | 61 | 227 | **3.6** |
| Western Baltic | 10 | 7 | **0.7** | 6 | 2 | **0.3** | 1 | 1 | **1.0** | 1 | 0 | **0** |
| Baltic proper . | 16 | 4 | **0.3** | 11 | 0 | **0** | 30 | 0 | **0** | 24 | 0 | **0** |

new environment. But the great changes from to year in the quantities of larvae make it ible that the fry which have drifted in will to their original habitat before their first ity.

shery for rough dab is not prosecuted by h fishermen, and so the fishery statistics do row any light upon the significance of the of larvae.

able 3 gives the total number of long rough aught in the eel-tog during the years 1927— in the Belt Sea, the western Baltic and the proper; it shows that in the Belt Sea, the most comprehensive investigations were d out, an increasing number of rough dab rs in the years 1931—1933, no doubt sponding partly to the comparatively prolific rence of rough dab larvae appearing in these s in the years 1929 and 1930 (see Table 1), , so far as 1933 is concerned, to the con- ible quantity of larvae appearing in 1932. 933 and 1934 the quantities decrease once ; in these two years the 1932 year-class a prominent part in the catches. In the rn Baltic a comparatively large stock of rough ccurred in the years 1930 and 1931. In the r year (1930) investigations in June estab- the presence of considerable numbers of dab throughout the western Baltic from the f Als to the line between Gedser and Dars. ength of the individuals caught varied be- 7 and 19 (23) cm., the average length being cm. (see Table 4); to judge from the length, of these specimens belonged to the I-group 1929 year-class), a few individuals being of - and III-group. In 1931 also young rough of the I-group (the 1930 year-class) (see 4) occurred abundantly in the western Baltic. numerousness of rough dab of the I-group in is in complete accordance with the fact that l specimens of the 0-group were taken in the western Baltic in October, 1929 (SW. of Vejsnæs, in a half-hour haul with the eel-tog, 24 individuals of 5—8 cm. in length). Such an abundance of the 0-group of rough dab in the western Baltic was not observed in any other year.

In the Baltic proper small numbers of rough dab were caught in the years 1927, 1928 and 1932; none of these individuals was taken east of Kriegers Flak.

## The Whiting *(Gadus merlangus).*

Whiting are common all over the Kattegat, the Belt Sea and the western Baltic and are met with sporadically in the western part of the Baltic

**Table 4. Length of *Drepanopsetta platessoides* caught with Eel-tog in the Western Baltic in the years 1930 and 1931.**

| cm. | 23.-30. June 1930 | 30. May 1931 |
|---|---|---|
| 7 | 2 | 1 |
| 8 | | |
| 9 | 9 | 5 |
| 10 | 11 | 9 |
| 11 | 16 | 5 |
| 12 | 26 | 14 |
| 13 | 10 | 4 |
| 14 | 12 | 2 |
| 15 | 4 | |
| 16 | 3 | |
| 17 | 3 | |
| 18 | | |
| 19 | 2 | |
| 20 | | |
| 21 | | 1 |
| 22 | | |
| 23 | 2 | |
| Total | 100 | 41 |
| M. Length cm. | 12.34 | 11.37 |

**Table 5. Length of Larvae of *Gadus merlangus* caught in different Danish Waters during the years 19**

| Area | Kattegat | | | North. Belt Sea | | | South. Belt Sea | | | West. Baltic | | | Baltic p | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Apr. | May | June | Apr. | May | June | Apr. | May | June | Apr. | May | June | Apr. | May |
| 3 mm. | 5 | | | | | | | | | | | | | |
| 4 „ | 26 | 1 | 1 | 2 | 1 | | | | | | | | | |
| 5 „ | 10 | 7 | 5 | | | | | | | | | | | |
| 6 „ | 3 | 13 | 1 | | 3 | | | 1 | | | | 1 | | |
| 7 „ | 2 | 13 | 3 | | 3 | | | 2 | | | | 5 | | |
| 8 „ | | 8 | 4 | | 1 | | | | | | | 5 | | |
| 9 „ | | 6 | 3 | | 2 | | | | | | | 2 | | |
| 10 „ | | 1 | 1 | | 2 | | | | 3 | | | 5 | | |
| 11 „ | | | 2 | | | | | | 1 | | | 2 | | |
| 12 „ | | 1 | 1 | | | | | | | | | 1 | | |
| 13 „ | | | | | | | | | | | | 1 | | |
| 14 „ | | | 1 | | | | | | | | | 2 | | |
| 15 „ | | 1 | | | | | | | | | | 1 | | |
| 16 „ | | | | | | | | | | | | 1 | | |
| 17 „ | | | | | | | | | | | | | | |
| 18 „ | | | | | | | | | | | | 1 | | |
| 25 „ | | | | | | 1 | | | | | | | | |
| 29 „ | | 1 | 1 | | | | | | | | | | | |
| 33 „ | | | | | | | | | | 1 | | | | |
| Total | 46 | 51 | 23 | 2 | 12 | 1 | | 3 | 4 | 1 | | 27 | | |
| M. Length | 4.4 | 7.5 | 8.8 | 4.0 | 7.4 | 25.0 | | 6.7 | 10.3 | 33.0 | | 10.1 | | |

proper. As a rule the whiting does not spawn in the southern parts of the Transition Area. It is true that rather large whiting with nearly mature roes or milts are not infrequent in the western Baltic, but the fact that larvae of whiting are so rare in this area seems to indicate either that these whiting with almost mature gonads leave our inner waters before spawning or that no larvae are developed from the eggs spawned by them.

But during all the years covered by our investigations, 1923 is the only year in which any considerable numbers of whiting larvae were found in the southern parts of the Transition Area (the Belt Sea and the western Baltic). The table below shows the numbers of larvae caught per half-hour haul in the various waters inside the Skaw from April to June, 1923.

In April whiting larvae did not advance further south than the northern half of the Kattegat. h in May they occurred throughout the Belt Sea any rate (for this month we have no investigatio of the western Baltic and the Baltic proper), a in June they were found as far within our wate as the Baltic proper between Kriegers Flak a the eastern coast of Falster; in the western Balt they were even comparatively numerous. Now th distribution of the larvae according to season a locality may mean either that spawning in o inner waters takes place later than outside the localities (which is the case so far as cod a concerned) or that currents have carried the larv into the southern waters from without. Table showing the lengths of the larvae, throws son light upon this point. In the Kattegat and, to lesser degree, in the northern Belt Sea there a found even in April many small, recently hatch

| | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of stations | No. of larvae | No. of larvae per half-hour haul | No. of stations | No. of larvae | No. of larvae per half-hour haul | No. of stations | No. of larvae | No. of larvae per half-hour haul |
| Kattegat | 22 | 6 | 0.3 | 12 | 144 | 12 | | | |
| Belt Sea | 5 | 0 | 0 | 9 | 81 | 9 | 4 | 6 | 1.5 |
| Western Baltic | 12 | 0 | 0 | | | | 10 | 38 | 3.8 |
| Baltic proper W.[1]) | 5 | 0 | 0 | | | | 13 | 2 | 0.2 |
| Baltic proper E.[1]) | | | | | | | 24 | 0 | 0 |

[1]) Respectively west and east of the line Smygehuk-Arkona.

**Table 6. No. of Whiting *(Gadus merlangus)* caught in the Eel-tog pr. 30 min. in the years 1927—35 in the Belt Sea, the Western Baltic, and the Baltic proper.**

| | 1927 | | | 1928 | | | 1929 | | | 1930 | | | 1931 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. |
| Belt Sea ..... | 42 | 29 | **0.7** | 87 | 183 | **2.1** | 44 | 250 | **5.7** | 65 | 199 | **3.1** | 91 | 164 | **1.8** |
| Western Baltic.. | 6 | 2 | **0.3** | 10 | 37 | **3.7** | 1 | 0 | **0** | 18 | 5 | **0.3** | 7 | 13 | **2.0** |
| Baltic proper... | 59 | 5 | **0.1** | 58 | 2 | **0.04** | 3 | 0 | **0** | 25 | 3 | **0.1** | 13 | 2 | **0.2** |

| | 1932 | | | 1933 | | | 1934 | | | 1935 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. | No. of stat. | No. of ind. | ind./ 30 min. |
| Belt Sea ..... | 86 | 412 | **4.6** | 41 | 371 | **9.0** | 55 | 232 | **4.3** | 61 | 357 | **5.9** |
| Western Baltic.. | 10 | 53 | **5.3** | 6 | 1 | **0.1** | 1 | 1 | **1.0** | 1 | 14 | **14.0** |
| Baltic proper . | 16 | 1 | **0.06** | 11 | 6 | **0.5** | 30 | 136 | **4.5** | 24 | 6 | **2.9** |

**Table 7. Total No. of Whiting *(Gadus merlangus)* of different age-groups caught in the Eel-tog in the Belt Sea, the Western Baltic, and the Baltic proper in the years 1927—35.**

| Year | 1927 | | | 1928 | | | 1929 | | | 1930 | | | 1931 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age-Group | Belt Sea | Western Baltic | Baltic proper | Belt Sea | Western Baltic | Baltic proper | Belt Sea | Western Baltic | Baltic proper | Belt Sea | Western Baltic | Baltic proper | Belt Sea | Western Baltic | Baltic proper |
| 0 ..... | | | | 131 | 25 | | 207 | | | 125 | | 2 | 104 | 6 | |
| I ..... | 10 | | | 25 | 5 | | 10 | | | 24 | | | 15 | 2 | |
| II ..... | 8 | 1 | 5 | 7 | 2 | | | | | 18 | | | | | |
| III ..... | 7 | | | 4 | 4 | | | | | 3 | | | 2 | | |
| IV ..... | 1 | | | | | | | | | | | | | | |
| V ..... | | | | | | | | | | | | | | | |
| VI ..... | 1 | | | | | | | | | | | | | | |
| VII ..... | | | | | | | | | | | | | | | |
| Tot. No. of ind. analysed for age | 27 | 1 | 5 | 167 | 36 | | 217 | | | 170 | | 2 | 121 | 8 | |

| Year | 1932 | | | 1933 | | | 1934 | | | 1935 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age-Group | Belt Sea | Western Baltic | Baltic proper | Belt Sea | Western Baltic | Baltic proper | Belt Sea | Western Baltic | Baltic proper | Belt Sea | Western Baltic | Baltic proper |
| 0 ..... | 159 | 53 | | 93 | | | 112 | | 114 | 24 | | |
| I ..... | 19 | | 1 | 77 | | | 40 | 1 | 9 | 185 | 13 | 5 |
| II ..... | 1 | | | 14 | | | 17 | | 1 | 17 | | |
| III ..... | | | | | | | 6 | | | 13 | | 1 |
| IV ..... | | | | | | | 2 | | | 6 | | |
| V ..... | | | | | | | 2 | | | 1 | | |
| VI ..... | | | | | | | | | | | | |
| VII ..... | | | | | | | 1 | | | | | |
| Tot. No. of ind. analysed for age | 179 | 53 | 1 | 184 | | | 180 | 1 | 124 | 246 | 13 | 6 |

ae with a length of 3 to 5 mm. In the hern Belt Sea and the western Baltic, on the r hand, none of the larvae is under 6 mm. ength, and in the Baltic proper the only larva sured was 13 mm. long. Thus we find the same state of things in this case as in the case of the long rough dab: recently hatched larvae are found only in the northern areas. The varying size-distribution of the larvae within the different waters shows that the stock of whiting larvae found

in the southern part of the Transition Area was not hatched there but was carried in from without.

It was mentioned above that comparatively large numbers of whiting larvae appeared in the southern part of the Transition Area in 1923, but during all the following years down to 1935 inclusive there were found no, or at any rate very few, larvae in these waters (see Table 1): the years 1928, 1929, 1930, 1934 and 1935 yielded quite small catches of whiting larvae in the Belt Sea, but none in the other years. In the western Baltic no whiting larvae at all were found from 1924 to 1935, while in the Kattegat they were very few in number. The year 1928 seems to be the only year in which investigations (carried out in the month of June) established the occurrence of a fairly large quantity of larvae in the Kattegat (38 specimens per half-hour haul).

Thus the investigations show that of the years under consideration 1923 is the only one in which whiting larvae in noteworthy numbers advanced into the southern parts of the Transition Area.

The occurrence of growing whiting (catches in eel-tog) in the inner parts of the Transition Area is illustrated by Tables 6 and 7. Table 6 shows that comparatively large numbers of whiting were taken in the western Baltic in 1928, 1931, 1932 and 1935, and in the Baltic proper — to a far smaller extent — in the years 1934 and 1935. In the Belt Sea the years 1933, 1935, 1929, 1932 and 1934 were more or less rich in whiting, 1927, 1931, 1928 and 1930 being comparatively poor years. It will be noticed that the occurrences of rich and poor years do not coincide very closely in these three sea areas, a feature doubtless mainly ascribable to the small extent of investigations carried out in the western Baltic. Only the year 1935 indicates the presence of a fairly large stock of whiting in all three waters. But the investigations as a whole agree with the larvae investigations in so far as the latter do not furnish evidence of any good spawning year from 1927 to 1935 or during the immediately preceding years.

Consideration of Table 7 will show that the years 1928, 1932 and 1934 yielded relatively large numbers of individuals of the 0-group in the western Baltic, and 1934 in the Baltic proper, specimens of the 0-group in this year being taken as far eastwards as between Rügen and Bornholm. This pronounced inroad southwards of the 0-group of whiting in the years 1928 and 1932 corresponds with the distribution of two other species of the cod family in these waters. In 1928 the 0-group of haddock advanced far into the Belt Sea, and in 1932 the 0-group of saithe (coalfish) and, to a lesser degree, of haddock occurred throughout the Kattegat and in part of the Belt Sea and the Sound. The fact that the years 1928, 1932 and 1934 exhibited a fairly rich stock of 0-group whiting in the inner parts of the Transition Area, while at the same time showing few larvae or no at all, seems to indicate that the stock of whiti does not depend principally on the inflow larvae, but is also determined by the immigrati of young fish.

## The Haddock *(Gadus aeglefinus).*

Inside the Transition Area the spawning of haddock normally takes place only in the northe Kattegat and larvae are not found south of deep eastern parts of the central Kattegat. In 19 however, — and this has already been dealt w in the literature[1]) — haddock larvae advanced far as the western Baltic, and in 1928 some f specimens were taken in the northern part of t Belt Sea. In both years the greatest numbers larvae occurred in May and June. The larvae w rather large, in May and June, 1923, averagi 15 mm. (7 individuals), in June, 1928, 20 m (3 individuals); in April, 1923, no haddock larv were found in the Belt Sea or in the weste Baltic, nor did they occur in the Belt Sea in M 1928. The late occurrence of the larvae and th size suggest that they did not result from a loc spawning but had been carried in from witho an assumption fitting in well with the fact th a marked inflow of salt water to the southern pa of the Transition Area took place in the ea summer of these two years. In 1929 haddoc although in small numbers only, advanced rath far into the Transition Area, where the numbe of larvae caught in May per half-hour haul wi the ring-trawl amounted to 0.3 in the Belt Sea a to 0.2 in the western Baltic. In the years 1930— haddock larvae were taken exclusively in t Kattegat, but in 1932 (April) considerable nu bers were caught in the central and southern pa of the area: between Kullen and Anholt 1 specim per half-hour (2 stations), between Anholt a Læsø (2 stations) 14, between Læsø and the Ska (2 stations) 40 and finally in the Skagerak a the north-eastern North Sea (4 stations) 11 indiv duals per half-hour. In the shallower western pa of the Kattegat, on the contrary, no haddock larv occurred. In 1933 some few haddock larvae we taken in the northern Kattegat and 1 specimen the northernmost part of the Belt Sea. In 19 and 1935 no haddock larvae at all were caug inside the Skaw, but it should be mentioned th there are no investigations in the northernmost pa of the Kattegat recorded for these years.

It may then be said that an intense inflow haddock larvae took place in 1923, and le pronounced inflows in the years 1928, 1929 an 1932.

The lengths of the larvae caught in 1932 ( the end of April) may be seen from the followin survey (number of individuals in brackets).

[1]) A. C. Johansen: 1926, l. c.

| | minimum length | maximum length | mean length in mm. |
|---|---|---|---|
| hern Kattegat . | 11 | 25 | 15.2 (6) |
| ral Kattegat .. | 7 | 29 | 12.6 (28) |
| hern Kattegat . | 6 | 23 | 12.4 (60) |
| gerak and north-stern North Sea | 6 | 15 | 10.7 (86) |

From this it may be seen that the larvae are h longer in the southern Kattegat than in the hern Kattegat and the Skagerak at the same , which proves that the individuals occurring e southern Kattegat came in from the north and not originate from a scanty spawning within e waters.

Thus haddock larvae occurred in the Belt Sea he years 1923, 1928, 1929 and 1932. This es with the fact that the investigations of the od 1927—1935 established the presence, ough in small numbers, of haddock of the oup in the Belt Sea and the western Baltic 928 and in the Belt Sea in 1932. Older had- were not caught in the eel-tog during this od, nor do the statistics of the commercial ries for these years indicate that haddock rred in these waters in any considerable tity.

## e Saithe or Coalfish *(Gadus virens).*

he spawning area of the saithe is situated even er away than that of the haddock, right in orthern and north-western part of the North In concordance with the remoteness of the ning area, larvae and fry of saithe are much frequent in the inner Danish waters than the of haddock and of the other species of fish ioned above. However, larger saithe are larly found in not inconsiderable numbers in orthern Kattegat, and from this region several iduals advance as far as the deep channels e Sound and the Belt Sea, some few of them taken now and again even in the deeper of the western Baltic. As a rule, however, e and young fish are not caught in the waters e the Skaw.

evertheless, in the years 1923 [1]) and 1932 [2]), worthy numbers of saithe larvae appeared ghout the Kattegat as far as the northern of Sealand, and in 1933 quite a few mens were caught in the northern Kattegat.

s regards the distribution of the different of larvae inside the various waters, the same res assert themselves as were observed in the of the haddock:

| | minimum length | maximum length | mean length in mm. |
|---|---|---|---|
| Southern Kattegat | 10 mm. | 27 mm. | 18.6 mm. (57 ind.) |
| Central Kattegat | 11 mm. | 26 mm. | 17.1 mm. (57 ind.) |
| Northern Kattegat | 10 mm. | 26 mm. | 15.9 mm. (44 ind.) |
| Skagerak NE. and NW. | 8 mm. | 23 mm. | 15.9 mm. (22 ind.) |

The greater lengths in the southern areas compared with those in the northern show that here, too, we are concerned with an inflow of larvae.

The saithe larvae appearing in 1932 remained in the waters they had entered and considerable quantities advanced even as far as the southern part of the Belt Sea. In 1933 large numbers of saithe (I-group) were caught in the Belt Sea and the Kattegat and some of them still remained as late as 1934, but during the winter of 1934/35 the capture of young saithe ceased. Apparently these fish, which were by that time 3 years old, had emigrated from these waters and returned to the spawning areas.

The growth of these inborne saithe appears from the measurements of length given below.

| Date | Average length cm. | Number of individuals |
|---|---|---|
| June 14—15, 1932..... | 5.8 | 8 |
| Aug. 11—25, „ ..... | 13.2 | 19 |
| Sept. 10—14, „ ..... | 15.9 | 30 |
| Dec. 29, „ ..... | 22.5 | 105 |
| Jan. 30, 1934..... | 32.3 | 76 |
| Mar. 13—20, „ ..... | 34.2 | 48 |
| Nov. 29, „ ..... | 43.1 | 7 |

Thus the average length at the end of the first, second and third growth periods was 22, 32 and 43 cm. respectively. That is to say, the growth in the first year was unusually rapid, but approximately normal during the two following years (as compared with the observations of Damas (2) on the coast of Norway.

## Poor Cod *(Gadus minutus).*

In the Transition Area this member of the cod family lives in the intermediate depths of the Skagerak and in the deep channel of the north-eastern Kattegat. Inside the Skaw its larval stages were found only in 1932 (in April), 5 larvae being caught per half-hour haul with the ring-trawl at a total of 14 stations in the Kattegat. The larvae occurred only in the deep eastern part of the Kattegat, but here they advanced as far south as Kullen.

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[1]) A. C. Johansen, 1926, l. c.

[2]) Erik M. Poulsen, 1933, l. c.

The average length of the larvae caught in the eastern Kattegat in April, 1932, increases in a southerly direction.

| | minimum length | maximum length | average length |
|---|---|---|---|
| Southern Kattegat | 6 mm. | 20 mm. | 13.7 mm. (19 ind.) |
| Central Kattegat | 6 mm. | 18 mm. | 10.7 mm. (58 ind.) |
| Northern Kattegat | 7 mm. | 14 mm. | 10.8 mm. (35 ind.) |
| Skagerak | 7 mm. | 17 mm. | 10.3 mm. (24 ind.) |

The higher average length of the larvae from the southern Kattegat indicates that the occurrence of larvae in this area is due to an inflow and not to a local spawning in the area.

In the channels of the northernmost part of the Belt Sea older individuals of *Gadus minutus* were found in some years, viz., in 1928, 1934 and 1935, but not in 1933 or 1927 (these deep channels were not investigated during the years 1929—32).

## Norway Pout *(Gadus esmarki).*

The distribution of this species of cod fish is much the same as that of *Gadus minutus*, but its larvae seem to be more frequently found than those of the latter in the waters inside the Skaw: larvae of *Gadus esmarki* were taken in the Kattegat in 1908, 1923, 1925 and 1932; in 1923 they even occurred in small numbers in the Belt Sea.

Older specimens of *Gadus esmarki* were caught in the channels of the northernmost part of the Belt Sea in 1928, 1934 and 1935, but not in 1933 or 1927. Thus their appearance coincides with that of *Gadus minutus*. Furthermore, in the spring of 1926, 8 specimens of *Gadus esmarki* were taken (in a one-hour haul with the otter seine) north of Als in the southern part of the Little Belt; of these 8 individuals 1 (13 cm.) belonged to the I-group (the 1925 year-class) and 7 (17—20 cm.) to the III-group (the 1923 year-class); that is to say, they originated from the very years in which investigations have established that an inflow of larvae took place.

## Anchovy *(Engraulis encrasicholus).*

The anchovy is an extremely rare visitor in the waters inside the Skaw, the southern and south-western part of the North Sea being the nearest area in which it occurs regularly and in abundant numbers. From here it advances in small numbers into the eastern and north-eastern part of the North Sea, where some individuals are taken almost every year, along the west coast of Jutland and in the western part of the Limfjord. Howev during recent years it has visited most of Transition Area in larger numbers, some f specimens having even advanced far into t Baltic. Thus P. Fr. Meyer (8) reports that November and December, 1933, the daily catc per boat in several localities of the western Bal amounted to 10—25 kg. of anchovy. But as ea as January, 1934, the fish had disappear Furthermore, it is stated by Kl. Bahr (1) th one specimen (14.5 cm. long) was caught off t coast of East Prussia in November, 1933.

The anchovy appeared also off the Dani coasts of the Transition Area during recent yea Strange to say there is no report of its occurren here in 1933 (as was the case off the Germ Baltic coast), but it was observed in the summ of 1934. In spring and throughout the summer this year a good many anchovy were caught various parts of the northern Belt Sea, for instan in Sejrö Bay and Aarhus Bay. In the form neighbourhood catches were particularly heavy June, the pound-nets often producing as much 25—30 kg. a night. A sample of these anchov taken in a pound-net on the 4th July, 1934, w examined, the lengths of the individuals being follows:

15 cm. — 11
16 cm. — 14
17 cm. — 2

27 — average length 15.7 cm.

Some of the females examined were on t point of spawning and perhaps had even begun spend their roe (maturity V and V—VI). T maturity of the males was approximately V. T anchovy had lost nearly all their scales, but t few scales remaining for examination had tw winter zones. For the purpose of ascertaining the anchovy were actually spawning here, a fe hauls were made with the Hensen net and the rin trawl near the places of capture on the 7th Jul but neither eggs nor larvae of anchovy were foun The anchovy caught in Sejrø Bay were nearly 1 cm. longer than those taken on the Baltic coast Germany in the winter of 1933—34; apparent the shoals visiting the two localities were identica During the month of July the numerical strength the stock of the northern Belt Sea decreased rapidl during the summer of 1935 a few specimens we caught in the northern Belt Sea. In 1934, too, t anchovy advanced far into the Baltic: on Nover ber 12th, 1934, a specimen of 19.5 cm. in leng was caught one nautical mile SE. of Bornholr and in October 1935 another specimen (18.5 cm E. of Bornholm.

## Review of the Fluctuations during recent rs in the Distribution of the Various cks of Fish within the Transition Area, and the causes thereof.

t appears from the preceding that the distri- on of some species of fish within the Transition a has been subject to considerable fluctuations n year to year, which are manifest partly in extension of the southern limit of the species uestion in some years a long way to the south- l (or eastward) of the limits of other years, ly in the occasional abundant occurrence of in species in southern waters where at other s they are sparse and sporadic.

With few exceptions (anchovy, mackerel and, ome extent, whiting) this extension of the di- ution is due to the fact that in some years larvae are carried farther southwards than in rs. In contrast with this inflow of larvae, the igration of older fish (with the above-men- ed exceptions) seems to be of little importance. eover it appears that the inborne larvae thrived their new environment, although this often ers very much from that in the normal growth s of the larvae and young fish. Normally the dock does not grow up in water with a ity of less than 32 $^0/_{00}$ (the northern Katte- . but in 1923 the haddock larvae that had been ied into the western Baltic were living at a ity of only 18 or 19 $^0/_{00}$. The proper habitat ne saithe (the Skagerak and the northern part ne North Sea) shows a salinity of about 33 $^0/_{00}$, in 1932 this fish was found to be growing up e Sound and the Belt Sea at a salinity of only o 24 $^0/_{00}$. Furthermore, it appears that individuals entering as larvae emigrated on their first maturity — a proved fact in the case of saithe and haddock — the great majority of them before spawning had taken place. This shows that the normal distribution — the habitat — of a fish is less dependent upon the effects of the environment of the young fish (the larvae) than upon the conditions necessary for the spawning of the mature fish or perhaps even for the development of absolutely mature gonads. It is not the larval stages which are sensitive to local conditions so much as the stages during which the maturing of the sexual elements is brought to completion.

In the main the greater or lesser degree to which a fish-stock advances towards the south is determined by the more or less extensive scale of the inflow of larvae of the species in question, and it has already been mentioned that the inflow of larvae depends on the strength of the southerly marine currents. I have attempted below to illustrate these circumstances by comparing the intensity of the inflow of larvae with the strength of the southerly currents, that is to say, with the changing salinities of the lower water layers. For the purpose of clearly expressing the advance of all fish larvae dealt with during the various years in the waters inside the Skaw, I have drawn a graph, which is intended to comprise all the species within the whole of the area examined: a comparison shows that the number of larval rough dab caught per haul in the Kattegat amounts to approximately twice the number caught in the Belt Sea and 14 times the quantity taken in the western Baltic. Accordingly, the values given in the "comprehensive" graph to a larva from the Kattegat, the Belt Sea and the

**Table 8. Calculated figures indicating the strength of the inflow of larvae of the different species into the Kattegat, the Belt Sea and the Western Baltic taken as a whole.**

| | 1904 | 1907 | 1908 | 1911 | 1923 | 1924 | 1925 | 1926 | 1927 | 1928 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Drepanopsetta plat.* .... | 41 | 2 | 15 | 3 | 131 | 0 | 9 | 9 | 6 | 0 |
| *Gadus merlangus* ..... | 2 | 0.1 | 0 | 0.5 | 16 | 0 | 0.1 | 0.1 | 3 | 0 |
| „ *æglefinus* ..... | 0 | 0.1 | 0 | 0 | 8 | 0 | 0.2 | 0.2 | 0.5 | 4 |
| „ *virens* ..... | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 |
| „ *esmarki* ..... | 0 | 0 | 0.1 | 0 | 2 | 0 | 0.1 | 0 | 0 | 0 |
| „ *minutus* ..... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Calculated figures for all species ..... | 62 | 4 | 32 | 8 | 773 | 0 | 29 | 22 | 43 | 36 |

| | 1929 | 1930 | 1931 | 1932 | 1933 | 1934 | 1935 | Mean |
|---|---|---|---|---|---|---|---|---|
| *Drepanopsetta plat.* .... | 22 | 14 | 5 | 12 | 3 | 16 | 3 | 17 |
| *Gadus merlangus* ..... | 1 | 3 | 0 | 1 | 0 | 0.1 | 0.3 | 1.6 |
| „ *æglefinus* ..... | 13 | 0.3 | 0 | 3 | 4 | 0 | 0 | 1.9 |
| „ *virens* ..... | 0 | 0 | 0 | 2 | 0 | 0 | 0.1 | 0.2 |
| „ *esmarki* ..... | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0.1 |
| „ *minutus* ..... | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0.1 |
| Calculated figures for all species ..... | 150 | 49 | 5 | 594 | 39 | 18 | 15 | |

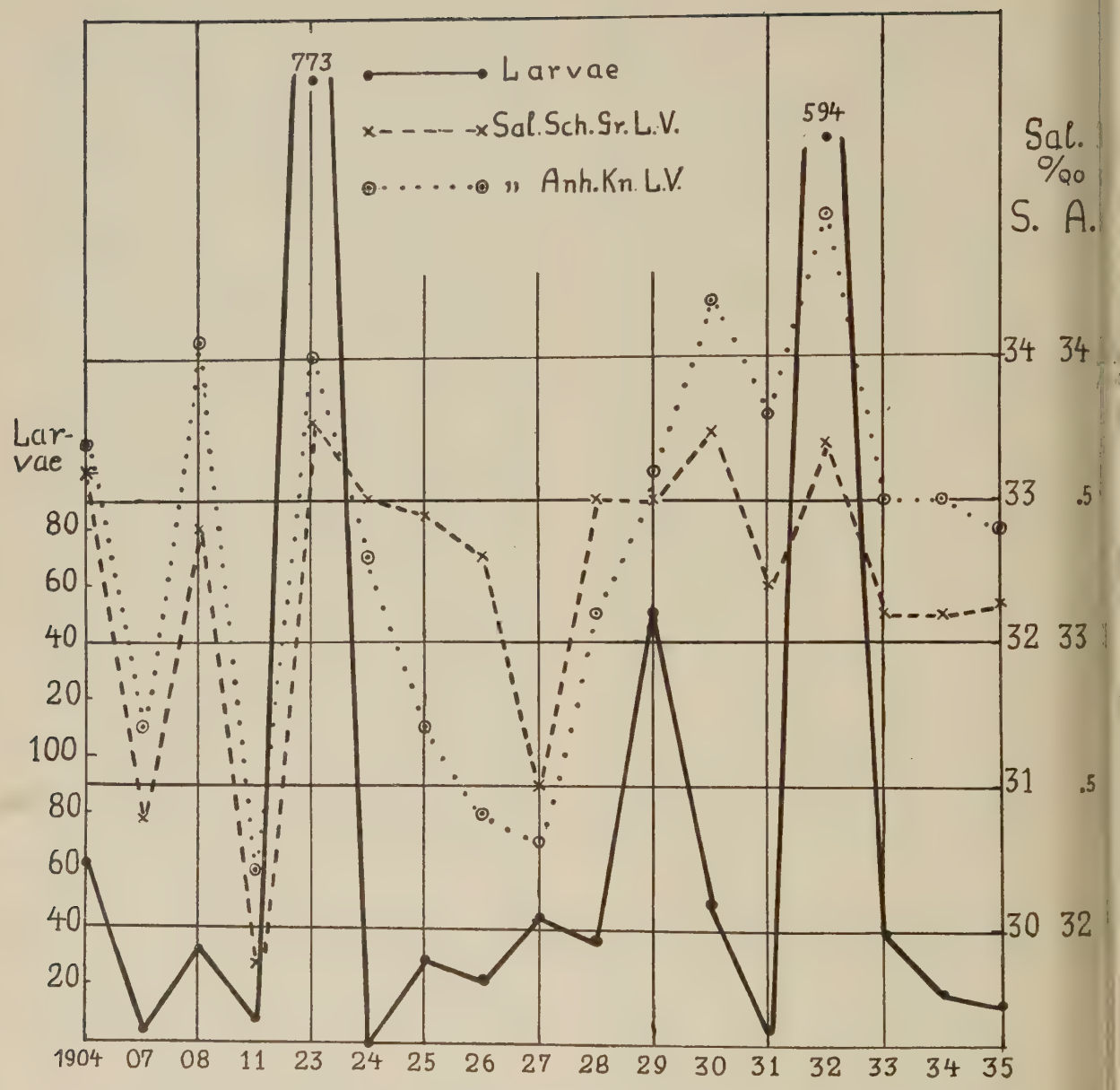


Fig. 2. Calculated figures for the inflow of larvae (see Table 8) compared with the salinities of the bottom water at Anholt Knob L. V. in April (A.) and at Schultz' Grund L. V. in April and May (S.).

western Baltic, respectively, are 1, 2 and 14. The same procedure is applied to the rest of the fish larvae. So we get for each larval species a series of figures (see Table 8), the total of which represents the annual advance of this species in the Kattegat, the Belt Sea and the western Baltic. The calculation was based on the average frequency of larvae in April and May. The average figures of the individual species for all years (the last colum of the table) show that the species are no of equal frequency within the areas examined *Gadus merlangus* and *G. aeglefinus* are by no means so frequent as *Drepanopsetta platessoides*. thus the occurrence of a certain number of larva of the two former species indicates a far more intensive inflow of larvae than the corresponding

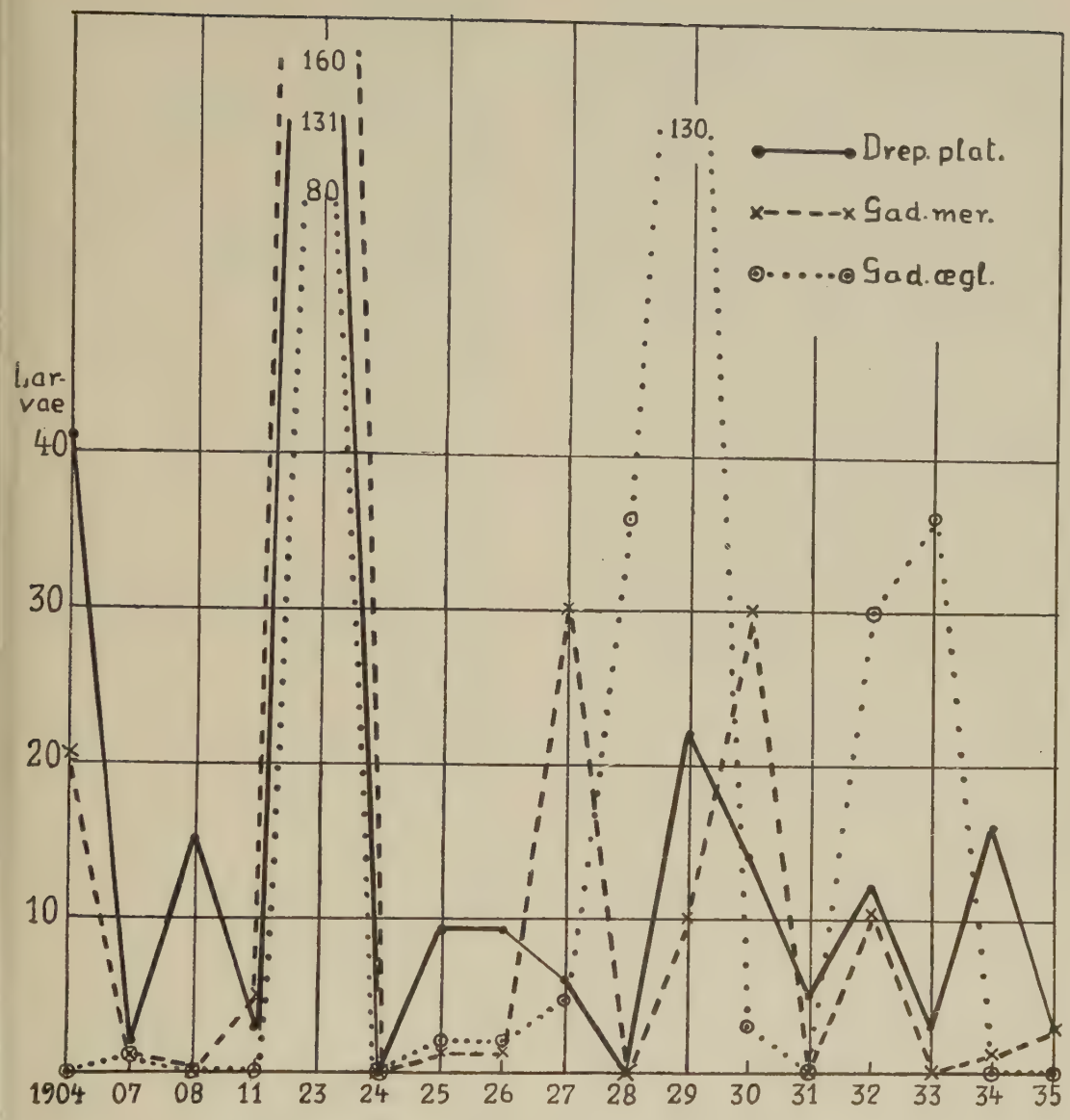


Fig. 3. Curves showing the yearly variations in the strength of the inflow of larvae of *Drepanopsetta platessoides, Gadus merlangus* and *G. æglefinus* into the inner Danish waters. The curves are based on the figures in Table 8, those for *G. merlangus* and *G. æglefinus* having been multiplied with ten.

ber of *Drepanopsetta platessoides. Gadus* as, *G. esmarki* and *G. minutus* are even much e infrequent than the species mentioned above. efore, when plotting out these six species ther in a single graph, we shall have to iply the calculated number of the species by gure representing their relative scarcity in parison with *Drepanopsetta platessoides.* By adding up the figures obtained in this way we get for each year a single figure indicating the intensity of the inflow of larvae. These figures are given in the lower series of the table and constitute the basis of the graph of Figure 2. It is seen from this figure that two years, 1923 and 1932, showed a particularly pronounced inflow. It will be remembered that these very years have

already been etablished as years of inflow, 1923 as regards haddock and 1932 as regards saithe. The next best years of inflow are 1929 and 1904.

The figure contains a graph showing the salinity of the bottom water at the Anholt Knob Lightship (in the middle of the Kattegat) in April and at the Schultz' Grund Lightship (at the northern entrance of the Belt Sea) in April and May. It will be seen that on the whole the curves of salinity and inflow of larvae show considerable similarity one to another, so that years characterized by an extensive inflow of larvae show a high salinity during the spring months. But the converse does not always apply: in 1924 salinity was high during the spring months, but nevertheless there was absolutely no inflow of larvae. Apparently a pronounced inflow of salt water is only one of the causes leading to an inflow of larvae. Abundance of fry in the area from which the larvae are coming is, of course, an obvious postulate for an intensive inflow of larvae: the year 1923, in which large quantities of haddock larvae were found to flow in, was an exceptionally good haddock brood year. The year 1924 was a moderately good brood year so far as haddock is concerned: in this year no inflow of larvae was observed in spite of the rather high salinity during the spring months. The fact that a strong inflow of salt water does not necessarily cause a strong inflow of several species of larvae, but only of one or two species, the larvae of which were numerically strong in the year in question, shows that the extent of the inflow of larvae is caused not only by the inflow of salt water, but also by the quantity of fry produced.

It appears from Figure 3, the graphs of which are based upon the values in Table 8, that, with the exception of the year 1923 and, to a lesser degree, of 1932, there is no marked correspondence between the inflow of the different species throughout the series of years. The numbers of inborne larvae of long rough dab were comparatively high in 1904 and 1929, whereas the whiting had distinct maxima in 1927 and 1930 and the haddock in 1928, 1929 and 1933, the saithe showing only one distinct maximum, which occurred in 1932. Finally it may be mentioned that a pronounced maximum of the long rough dab occurred in 1934, a year in which all other species were extremely few in number.

With regard to the changing extent of the inflow of larvae during the period under consideration, w may set forth the following general facts: so far the material of the investigation goes, we ha noted the inflow to be fairly large in 1904, rath small in 1908 and extremely small in 1907 a 1911. The most intensive inflow was observed 1923; in 1924 it failed and in 1925 and 1926 it w fairly small. The inflow is somewhat larger 1927 and on about the same level in 1928; in 19 it was very large, in 1930 rather large, but in 19 extremely small. Like 1923, the year 1932 sho an exceptional inflow of larvae, but in 1933 t amount decreases considerably and is only small 1934 and 1935. In other words, the period 1923- 1935 is characterized by a large inflow in 19 and 1932, a less marked inflow in 1927—193 while during the intermediate years the inflow wa more or less inconspicuous.

Simultaneously with the inflow of larvae w have in some cases observed an inflow, or rath an immigration, of young fish (the bottom stage the 0-group and older specimens), more particular in the case of the whiting and, to some degree, the saithe; the bottom stages of the 0-group an the I-group of these species were found to advan farther into our waters than the larvae of the sam species. A corresponding immigration of youn fish of the other species dealt with here (th remaining species of the cod family and the lon rough dab) could not be established on the basis o the material in hand. Most probably the imm grations of young fish have been less important i the case of these bottom feeders than in the cas of the saithe and the whiting. An abundant immi gration of the more pelagic species, such a mackerel, horse mackerel and anchovy, was observe in the years 1928—1934.

The investigations mentioned above have show that inside the Transition Area the regiona distribution of several species of fish is subject t shifting towards the south and east in certain year or periods of years. The extent of these shifting depends partly upon the strength of the southerl marine currents, partly upon the amount of fr produced by the species in question. These move ments are of only a temporary nature and do no bring about any permanent changes in the fis fauna of the Area.

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# IV.

# ÜBER DAS VORKOMMEN VON SCHELLFISCHEN IN DER WESTLICHEN OSTSEE.

VON

DR. K. ALTNÖDER.

(MS. received August, 1936)

den früheren Jahren wurde der Schellfisch in er westlichen Ostsee nur vereinzelt gefangen. So gibt Heincke-Möbius in "Die Fische Ostsee" an: "In der Kieler Bucht wird er im er und Frühjahr seltener im Sommer mitunter er Angel gefangen. Hier messen die grössten plare 60 cm. Weiter östlich als bis an die llenburgische Küste ist er nicht beobachtet en."

n Winter 1925 und 1926 trat dagegen der lfisch in der westlichen Ostsee in bisher noch eobachteter Menge auf. So betrugen die Angen 1925 64,501 kg., und 1926 136,066 kg. s plötzliche enorme Auftreten von Schellen kam nicht unangemeldet. Nach einer Mitng von Professor Steyer, Lübeck, wurden s im Oktober 1923 zahlreiche kleine Schell- von 15 cm. Länge in der Eckernförder Bucht chtet. Im April 1925 lag die mittlere Länge 1 cm. und im folgenden Jahr bei 38 cm.

ie Schellfischanlandungen in den oben erten Jahren beruhten alle auf dem Jahrgang

ähere Einzelheiten über das Vorkommen der lfische in den Jahren 1925 und 1926 finden n folgenden Abhandlungen:

. Johansen: Beretning om Kommissionen r Havundersøgelsers Virksomhed i 1923/24. iskeriberetning for 1923. København 1924.

Johansen: On the Remarkable Quantities Haddock in the Belt Sea during the Winter 925/26, and causes leading to the same. Journ. Conseil, Vol. I, 1926.

. Joh. Petersen: Rapp. over Biologisk ations Virksomhed i 1923. Fiskeriberetning r 1923, København 1924.

ischer: Das Auftreten von Schellfischen in r westlichen Ostsee. Mitteilungen des D. S. V. l. XXXXII.

eidrich: Der Schellfischfang in der westchen Ostsee. Der Fischerbote, XVIII. Jahrg. 926.

ach 1926 gingen die Erträgnisse im Schellang wieder stark zurück. So wurden

| | | |
|---|---|---|
| 1927 | ..... | 17,470 kg. |
| 1928 | ..... | 5,756 „ |
| 1929 | ..... | 4,520 „ |
| 1930 | ..... | 9,850 „ |

andet. Der Rückgang ist darauf zurückzuführen, dass ein grosser Teil der Schellfische durch den Eintritt der Laichreife abgewandert war. Der Anstieg 1930 erfolgte dagegen wieder durch ein erneutes Auftreten jüngerer Schellfische. Wie in dem Artikel (Mitteilungen des D. S. V. Bd. XXXXVI, Nr. 6) "Neues Auftreten von Schellfischen in der Ostsee" von Dr. K. Altnöder dargelegt ist, wurden im Winter 1929/30 des öfteren in der Travemünder Bucht kleinere Schellfische beobachtet. Am 10. März 1930 wurde eine grössere Probe (425 Stück) von 18—35 cm. untersucht und die Altersbestimmung ergab 81 % des Jahrgangs 1929 und 19 % des Jahrgangs 1928. Ferner wurde am 13. August des gleichen Jahres in Travemünde eine Probe von 25 Stück von 25—29 cm. untersucht, die dem Jahrgang 1929 angehörten. (Vergleiche auch Erik M. Poulsen: The Haddock in the Belt Sea and the Western Baltic during the years 1926—28. Rep. Dan. Biol. Stat. XXXIV, 1928).

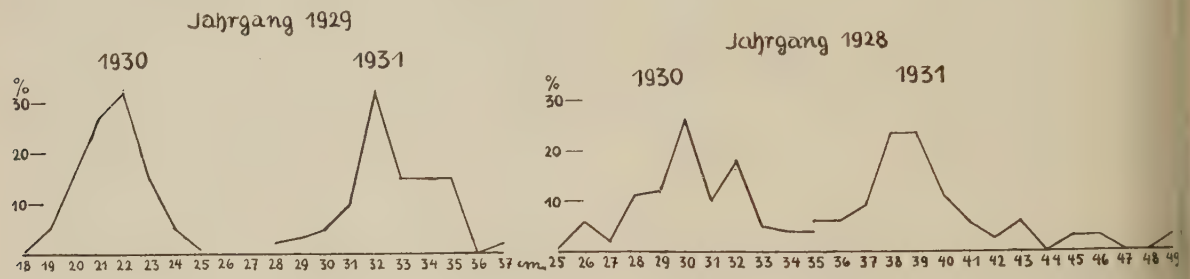
Weitere Untersuchungen wurden im Februar und März 1931 in Eckernförde vorgenommen. Es wurden einige Proben aus Zeesenfängen bearbeitet und die Altersanalyse zeigte nachstehendes Bild.

| | | Länge in cm. | | | |
|---|---|---|---|---|---|
| Jahrgang: | | 1929 | 1928 | 1927 | 1925 |
| 28 cm. | ..... | 1 | — | — | — |
| 29 „ | ..... | 2 | — | — | — |
| 30 „ | ..... | 3 | — | — | — |
| 31 „ | ..... | 6 | — | — | — |
| 32 „ | ..... | 19 | — | — | — |
| 33 „ | ..... | 9 | — | — | — |
| 34 „ | ..... | 9 | — | — | — |
| 35 „ | ..... | 9 | 2 | — | — |
| 36 „ | ..... | — | 2 | — | — |
| 37 „ | ..... | 1 | 3 | — | — |
| 38 „ | ..... | — | 8 | — | — |
| 39 „ | ..... | — | 8 | — | — |
| 40 „ | ..... | — | 4 | — | — |
| 41 „ | ..... | — | 2 | — | — |
| 42 „ | ..... | — | 1 | — | — |
| 43 „ | ..... | — | 2 | — | — |
| 44 „ | ..... | — | — | — | — |
| 45 „ | ..... | — | 1 | — | — |
| 46 „ | ..... | — | 1 | — | — |
| 49 „ | ..... | — | 1 | — | — |
| 50 „ | ..... | — | — | 1 | — |
| 57 „ | ..... | — | — | — | 1 |
| Anzahl | ..... | 59 | 35 | 1 | 1 |

61 % gehörten dem Jahrgang 1929 und 36 % dem Jahrgang 1928 an. Die Jahrgänge 1925 und 1927 waren nur mit je einem Stück vertreten.

Zusammenfassend ist zu sagen, dass die Schellfischfischerei 1930 und 1931 in der westlichen Ostsee auf den Jahrgängen 1928 und 1929 beruhte. Dabei kommt dem letzteren Jahrgang die grössere Bedeutung zu.

Das Wachstum der Jahrgänge 1928 und 1929 vom Winter 1930 bis 1931 veranschaulicht die folgende Abbildung.




Der Jahrgang 1929 umfasste im Winter 1930 Fische von 18—25 cm., 1931 solche von 28—37 cm. Für den Jahrgang 1928 bewegte sich 1930 die Länge zwischen 25—35 cm. und 1931 zwischen 35—49 cm.

Wie sich das Auftreten von Schellfischen in den Jahren 1931—35 in der westlichen Ostsee gestaltet hat, darüber geben die Anlandeziffern Aufschluss. Danach wurden angelandet

| | | |
|---|---|---|
| 1931 | 1,990 | kg |
| 1932 | 1,498 | „ |
| 1933 | 719 | „ |
| 1934 | 780 | „ |
| 1935 | 759 | „ |

Die angebrachte Menge liegt demnach weit u der der Jahre vor 1930. Um welche Jahrgäng sich seit 1932 handelte, konnte nicht unters werden. Die einzelne Fänge waren sehr klein die Fischer hatten daher eine Benachrichtig unterlassen.

Bezüglich der Verbreitungsgrenze des Sch fisches in der Ostsee ist zu bemerken: H e i n c M ö b i u s gibt als östliche Verbreitungsgrenze Mecklenburger Küste an. Nach den Beobachtun von Dr. M a r q u a r d wurden dagegen in Jahren 1926—30 verschiedene Schellfische in mittleren Ostsee gefangen, wie die nachfolge Zusammenstellung zeigt, die seiner Arbeit "B träge zur Kenntnis der Ostseefische und ihrer V breitung" (Mitteilungen des D. S. V. Bd. XXXX Nr. 3) entnommen ist.

| Nr. | Grösse cm. | Gewicht kg. | Fangort | Entfernung Sm. Tiefe m. | Datum | Zahl |
|---|---|---|---|---|---|---|
| 1 | 45 | 1 | Bornholmsee | 33 Sm. NW. v. Stolpmünde | 30.IV.26 | 1 |
| 2 | 65 | 2 | vor Rügenwaldermünde | 5 Sm., 20 m. | XI.26 | 1 |
| 3 | 63 | 2 | Bornholmsee | 25 Sm. NW. v. Kolberg, 50 m. | II.30 | 1 |
| 4 | 40—60 | je 1—3 | zw. Stolpmünde u. Rügenwaldermünde | 4 Sm., 10—15 m. | II./III.27 | 15 |
| 5 | 55 | 3 | zw. Scholpin u. Leba | 5 Sm., 25 m. | X.28 | 1 |

Die unter 1, 4 und 5 aufgeführten Schellfische gehörten dem Jahrgang 1923 an. Nach schriftlicher Mitteilung von cand. rer. nat. P i l w a t, Seefischerei-Station Neukuhren, wurde im August 1936 ein Schellfisch etwa 6 Sm. nördlich von Neukuhren gefangen.

V.

# DREPANOPSETTA-BESIEDLUNG DER WESTLICHEN OSTSEE.

## E FOLGE VON LARVENVERFRACHTUNGEN IM JAHR 1930.

VON

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BERLIN.

(MS. received May, 1936)

U den häufigsten Gastfischen in der Ostsee gehörte in den letzten Jahren die in der Nordsee beheimatete Scharbzunge *Drepanopsetta ssoides*[1]). Ihr Vorkommen beschränkte sich rossen und ganzen auf die Mecklenburger, ker und Kieler Bucht und den Fehmarn Belt. auptsächlichster Aufenthaltsort war die Meckrger Bucht und zwar der nördliche Teil etwa hen 54°23′ und 54°28′ N. und 11°25′ und 5′ O. Den südlichen und westlichen Teil der lenburger Bucht suchte die Scharbzunge nicht ufig auf. Ebenso fand man in der Lübecker nur vereinzelt Individuen. In den letzten drei n war sie auch dort stärker vertreten. Auch in nördlichen Teil der Kieler Bucht, in dem M o e- s und H e i n c k e (10) die ersten Drepanop- Funde machten, wurde sie in den letzten Jahren ger festgestellt. Der Osthang der Mecklenburucht wies nur bis zur 20 m.-Linie eine dichtere llung auf. Darüber hinaus nahm die Zahl rasch ab bis zur Darsser-Schwelle. Aus dem a-Becken liegen nur einige Funde vor: auf oseidon-Fahrt im April 1933 wurden auf Sta- X (54°51′ N. und 13°31′ O.) in 45 m. Tiefe ibchen von 23 und 29 cm. Länge gefunden, m August 1934 fand ich ein 17 cm. langes hen 17 Sm. NNO. von Sassnitz in 23 m. Der östlichste Fundort von Drepanopsetta ach M a r q u a r d (5) im südlichen Born-Becken in 50 m. Tiefe.

lle Fundorte lagen unter 20 m. Wassertiefe. ie Begrenzung der Wohngebiete dadurch bewar, dass Drepanopsetta eine Bewohnerin des en Wassers ist, oder ob Bodenverhältnisse und fauna die raumbegrenzenden Faktoren waren anopsetta ist Schlickbewohnerin und meidet und Steingrund), sei dahingestellt. Benswert war jedenfalls, dass in der nördlichen enburger Bucht, in der die Drepanopsettallung am dichtesten war, der schlickige Grund Besiedlung von *Ophiura albida* aufwies, die Magenuntersuchungen zeigten — neben an- Echinodermen fast die einzige Nahrung von nopsetta zu sein schien.

Wie im einzelnen in den Jahren 1933/34 die Besiedlungsdichte in der Mecklenburger Bucht war, habe ich schon früher mitgeteilt[2]):

**Tabelle 1.**

| Fangplatz | Tiefe | Datum | Anzahl von Drepanopsetta pro Fangstunde |
|---|---|---|---|
| 18 Sm. NW. Warnemünde | 20 m. | 7. VII. 1933 | 57.5 |
| 4—6 Sm. NO. Staberhuk | | 15. X. 1933 | 50.0 |
| 5—6 Sm. N. Heiligendamm | | 21. IX 1933 | 10.0 |
| Querab Dahmshöft | | 10. XII. 1933 | 2.0 |

Die Anregung zur näheren Untersuchung dieser in der Belt-See schon seit langem bekannten, immer wieder auftauchenden Fische[3]) gab ein Massenauftreten von Drepanopsetta im Jahr 1933 in den Klieschenfängen von Travemünde und Warnemünde. Die Drepanopsetta-Anlandungen nahmen 1933 solchen Umfang an, dass dieser Fisch nicht mehr wie bisher in die Klieschenfänge sortiert werden konnte, sondern gesondert als "Zunge" in den Handel gebracht werden musste. So bestand z. B. nach Schätzungen im Jahr 1933 in den Warnemünder Klieschenanlandungen folgendes Untermischungsverhältnis mit Drepanopsetta:

**Tabelle 2.**

| Monat | Klieschenanlandungen in kg. | Prozentsatz an Drepanopsetta |
|---|---|---|
| I—V | 49,187 | 20 % |
| VI—VIII | 17,944 | 50 % |
| IX—XII | 4,118 | 10 % |

In Travemünde waren die Drepanopsetta-Anlandungen im Verhältnis zu den Klieschenanlandungen noch grösser. So wurde z. B. am 15. VII. 1932 ein Fang angebracht (Fangplatz: 12 Sm. OSO. Staberhuk in 25—26 m. Wassertiefe), in dem das Mengenverhältnis von Kliesche und Drepanopsetta sich wie 100 : 360, oder am 7. X. 1933 (Fangplatz 5 Sm. O S O. Staberhuk 28 m. Wassertiefe) wie 100 : 116 verhielt. In den fangarmen Sommermonaten 1933 wurde zeitweise sogar nur auf Drepanopsetta gefischt.

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Das Verbreitungsgebiet von *Drepanopsetta platessoides* wird begrenzt im N. durch das Weisse Meer, im S. den Kanal, im O. durch die Belt-See.

Verfasser (9): Zeitschr. für Fischerei, 1934.

Vergl. L e n z (6), M o e b i u s und H e i n c k e (10).

Funde siehe auch S t r o d t m a n n (11, 12).

Die auffällige Drepanopsetta-Zunahme, die im übrigen schon 1932 in einer bis dahin unbekannten Weise an den beiden Märkten eingesetzt hatte, war auch 1934 zu spüren. Jedoch waren die Anlandungen in Warnemünde und Travemünde gegenüber 1933 erheblich geringer. Ebenso wie in den Fängen aus der Mecklenburger Bucht machte sich auch in den Plattfischanlandungen aus der Kieler Bucht eine steigende Drepanopsetta-Untermischung bemerkbar.

Nähere Angaben über die Rassenmerkmale, Alter usw. der eingedrungenen Gäste wurden bereits veröffentlicht (9). Wenn wir im Rahmen der von der Internationalen Meeresforschung in Angriff genommenen Bearbeitung des Materials über fremde Gäste in der Ostsee erneut zu dem Drepanopsetta-Problem in den westlichen Gebieten der Ostsee Stellung nehmen, so deshalb, um einige für die Ursache dieser Massenbesiedlung wichtige Untersuchungen aus dem Jahr 1934 nachzutragen; vor allem aber, um an dem Beispiel der Drepanopsetta-Besiedlung der Mecklenburger Bucht zu zeigen, unter welchen Voraussetzungen ein derartiger grosser Vorstoss ortsfremder Tiere in die Ostsee erfolgen kann und wie eine solche Massenverfrachtung sich auf Jahre in der Ostseefauna bemerkbar machen, ja wie sie auch eine gewisse fischereiliche Bedeutung haben kann.

Bereits in der ersten Veröffentlichung (9) wies ich auf die verschiedenen Möglichkeiten hin, wie das Eindringen von Drepanopsetta erfolgt sein könnte: 1. *Einwanderung* erwachsener Tiere evt. unterstützt durch Frühjahrs- oder Herbsteinströmungen von Nordseewasser in die Belt-See. 2. *Einschleppung* von Eiern oder Jugendstadien von Drepanopsetta. Auf Grund meiner früheren Untersuchungen glaubte ich die letzte Möglichkeit annehmen zu dürfen. Inzwischen haben Untersuchungen im letzten Jahr diese Meinung noch gestützt. Die Gründe, die ein Eintragen von Eiern bezw. Jugendstadien rechtfertigen, sind folgende:

1. Bestandsuntersuchungen haben ergeben, dass die Drepanopsetta-Anlandungen 1933 sowohl als 1934 zu etwa 70—80 % aus Tieren des Jahrganges 1930 bestanden. In einem Marktfang vom 7. III. 1933 aus der nördlichen Mecklenburger Bucht gehörten allein 81 % aller Tiere der Altersgruppe III (Jahrgang 1930), und 19 % der Altersgruppe IV (Jahrgang 1929) an. Alle anderen Jahrgänge fehlten:

(Tabelle 3.)

Auch 1934 beherrschte der Jahrgang 1930 den Marktfang vollständig. Bei einem am 20. VI. 1934 aus der nördlichen Mecklenburger Bucht in Warnemünde angebrachten Marktfang bestanden nicht weniger als 84 % dieses Fanges aus Altersgruppe IV (Jahrgang 1930), die übrigen 16 % bestanden aus Altersgruppe III, V und VI (Tab. 4).

## Tabelle 3.

**Altersgruppenverteilung im Drepanopsetta-Fang aus der Mecklenburger Bucht am 7. III. 1933.**

♀ (♂)

| Länge cm. | I (1932) | II (1931) | III (1930) | IV (1929) | Summe |
|---|---|---|---|---|---|
| 22 | — | — | —( 4) | — | 4 |
| 23 | — | — | 2(10) | — | 12 |
| 24 | — | — | 13( 8) | — | 21 |
| 25 | — | — | 2( 8) | — | 10 |
| 26 | — | — | 2(13) | 1(—) | 16 |
| 27 | — | — | —( 3) | 2( 4) | 9 |
| 28 | — | — | — | 1( 1) | 2 |
| 29 | — | — | — | 2( 1) | 3 |
| 30 | — | — | — | — | — |
| 31 | — | — | — | 1( 1) | 2 |
| 32 | — | — | — | 1(—) | 1 |
| Summe | — | — | 19(46) | 8( 7) | 80 |
| M | — | — | 24.44 | 29.35 | 24.4 |
| % | — | — | 81 | 19 | 10 |

## Tabelle 4.

**Altersgruppenverteilung im Drepanopsetta-Fang aus der Mecklenburger Bucht am 20. VI. 1934.**

♀ (♂)

| Länge cm. | I (1933) | II (1932) | III (1931) | IV (1930) | V (1929) | VI (1928) | Summe |
|---|---|---|---|---|---|---|---|
| 24 | — | 2( 1) | 2( 1) | 1(—) | — | — | 7 |
| 25 | — | — | 2(—) | 12(—) | — | — | 14 |
| 26 | — | — | — | 16(—) | — | — | 16 |
| 27 | — | 1(—) | 4(—) | 20(—) | — | — | 25 |
| 28 | — | — | — | 20( 1) | — | — | 21 |
| 29 | — | — | — | 22( 2) | — | — | 24 |
| 30 | — | — | — | 12(—) | 4(—) | — | 16 |
| 31 | — | — | — | 13(—) | 2(—) | 1(—) | 16 |
| 32 | — | — | — | 4(—) | 2(—) | — | 6 |
| 33 | — | — | — | 1(—) | 1(—) | — | 2 |
| 34 | — | — | — | 1(—) | — | — | 1 |
| Summe | — | 3( 1) | 8( 1) | 122( 3) | 9(—) | 1(—) = 148 | |
| M | — | — | — | 28.2 | — | — | 28.0 |
| % | — | 2 | 5 | 84 | 8 | 1 = 100 | |

Ebenso wie die Altersgruppenzusammensetzung ten auch die Grössenuntersuchungen der Dre- psetta-Fänge darauf hin, dass die Drepanop- -Anlandungen der letzten Jahre grösstenteils m Jahrgang angehört haben müssen, denn die ungsreihen wiesen im Laufe von 1933 und eine ständige Zunahme grösserer und eine hzeitige Abnahme kleinerer Individuen auf elle 5):

Der zweite Grund, der mich bewog, eine Verschleppung von Eiern oder Jugendstadien anzunehmen, war der, dass gerade in der fraglichen Zeit im April 1930 eine ausgezeichnete Verfrachtungsmöglichkeit für die Entwicklungsstadien der Drepanopsetta bestanden hat: Nach dänischen Feuerschiffbeobachtungen hatte im Frühjahr 1930 ein aussergewöhnlich starker Einstrom von Nordsee- und Atlantikwasser ins Skagerak und Kattegat

## Tabelle 5.

**Messungsreihen der Drepanopsetta-Fänge in Warnemünde 1933 und 1934 (Prozentreihen).**

| 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | Datum | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 15 | 25 | 12 | 20 | 5 | 8 | 3 | 4 | — | 2 | 1 | — | — | 7. III. 1933 | 22.5 |
| 1 | 3 | 11 | 13 | 19 | 17 | 8 | 7 | 5 | 3 | 2 | 1 | 1 | — | IX. 1933 | 26.7 |
| 1 | — | 4 | 10 | 11 | 17 | 14 | 15 | 11 | 10 | 6 | 1 | 1 | — | 20. VI. 1934 | 28.0 |
| — | — | 1 | 2 | 5 | 7 | 10 | 15 | 17 | 16 | 14 | 8 | 4 | 1 | 8. IX. 1934 | 30.0 |

eues hinsichtlich der in der Mecklenburger t vorkommenden Jahrgänge von Drepanopsetta te ein Fang mit einer Sprottzeese vom 22. IX. Er zeigte, dass sich auch einjährige Inuen in grösserer Zahl in der Mecklenburger t aufhielten. So bestand der Fang allein zu aus Altersgruppe I (Jahrg. 1932). Weitere gehörten der Altersgruppe IV (Jahrg. 1929) Der Rest war Altersgruppe III (Jahrg. 1930). ugust 1934 fing ich an der gleichen Stelle 3 Exemplare der Altersgruppe 0 (Jahrg. 1934) bis 6.5 cm. Länge. Larven und Eier sind hin- weder in der Kieler noch in der Mecklenbur- Bucht bisher gefangen worden (M i e l c k)[1]) will aber nicht viel besagen, denn im wesent-

stattgefunden, der im Laufe des Sommers auch auf allen Feuerschiffen bis Feuerschiff Gjedser-Rev bemerkt wurde:

Skagens Rev: Anfang Februar bis Anfang Juni,
Anholt Knob: Anfang März bis Anfang August,
Halskov Rev: Ende April bis Mitte August,
Gjedser Rev: Ende Juni bis Mitte August und Oktober/November.

Die Stärke des Einstroms ging aus Salzgehalt-Anomalien hervor, die auf "Gjedser Rev" 1930 festgestellt wurden. Die Angaben (‰) beziehen sich auf Bodenwasser in 17 m. Tiefe (Tabelle 6):

## Tabelle 6.

| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .. | — 3.8 | — | — | — 1.4 | — 1.3 | — 2.0 | — 1.3 | — 1.5 | + 0.6 | — 0.5 | — 3.5 | — 2.1 |
| .. | 14.1 | 14.0 | 15.1 | 14.8 | 15 | 15.7 | 14.6 | 14.1 | 14.8 | 13.7 | 12.9 | 13.6 |
| .. | — 2.8 | — 2.5 | — 1.4 | — 3.2 | — 1.4 | + 2.8 | + 3.7 | + 0.0 | — 0.4 | + 2.9 | + 5.3 | + 0.1 |

beschränkt sich das Planktonmaterial, das iesen Buchten vorlag, auf Proben, die gelegent- ler Terminfahrten des "Poseidon" genommen . Es gibt jedenfalls zu denken, dass die noch im Belt und Sund vereinzelte Larven gen haben. Nach freundl. Mitteilung von Dr. H. B l e g v a d, Kopenhagen, machte man herseits die südlichsten Funde von Drepanop- Larven Mitte April 1932 im Samsö-Belt N. auf 32 m. Wasser und zu gleicher Zeit im en Belt 55°36′ N. und 18°48′ O. auf 31 m. und wurde am 14. IV. 1932 eine Drepanop- Larve NO. Dragör erbeutet.

[1]) Auch K ä n d l e r hat nach mündlicher Mitteilung m von Oktober 1934 bis Oktober 1935 auf dem chiff "Fehmarn Belt" gesammelten Planktonmaterial Drepanopsetta-Eier oder -Larven gefunden.

(Die Monatsmittel wurden auf der Grundlage der Angaben nach dem Kriege berechnet).

Nach der Tabelle lag der Salzgehalt am "Gjedser Rev" in den Monaten Juni, Juli 1930 um 2.8 bezw. 3.7 ‰ und im Oktober/November 1930 um 2.9 bezw. 5.3 ‰ höher als das Mittel der letzten 10 Jahre. Es fand also in den Monaten Februar bis Juni 1930 ein ungewöhnlich starker und lang andauernder Einstrom von salzhaltigerem Nordseewasser in die Ostsee statt, der sich im Laufe des Sommers über die Beltsee hinaus bis zur Darsser Schwelle bemerkbar machte.

Nach E h r e n b a u m s Angaben über die Laichzeit von Drepanopsetta in der Nordsee (Januar bis Ende Mai, Hauptlaichzeit: April/Mai) ist anzunehmen, dass zum mindesten die Hauptlaichzeit mit dem Einstrom des Nordseewassers zeitlich

zusammenfiel und dass dadurch eine aussergewöhnliche Verfrachtungsmöglichkeit für die Entwicklungsstadien von Drepanopsetta vorhanden war.

Ob sich dieser vorgeschobene gut gewachsene Bestand in der Mecklenburger Bucht und den angrenzenden Gebieten auf die Dauer halten wird, ist sehr unwahrscheinlich. Denn es gibt zu bedenken, dass man wohl Tiere mit reifenden Laichprodukten in den Untersuchungsgebieten fand, aber dagegen kaum welche, die im Laichen begriffen waren oder ausgelaicht hatten. Die Vermutung lie nahe, dass sich die Tiere mit fortschreitender Laic reife in salzhaltigeres Wasser zurückziehen[1]). E Markierungsexperiment und weitere Beobachtunge können Aufklärung darüber bringen.

[1]) Auffällig ist, dass die Zeit der vorbereitenden Laic entwicklung in der Ostsee in beiden Untersuchungsjahr immer im Mai/Juni lag, während die eigentliche Laic periode in der Nordsee nach Ehrenbaum von Janu bis Ende Mai dauert mit einem Höhepunkt im März/Apri

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# Nachtrag.

## Die Drepanopsetta-Besiedlung der Mecklenburger Bucht in den Jahren 1934—1936.

Das Fehlen von Drepanopsetta-Larven und -Eiern, sowie das Fehlen von laichenden oder abgelaichten Tieren in der Mecklenburger Bucht liess schon bei Abschluss der obigen Untersuchungen im Juni 1934 die Vermutung aufkommen, dass der über die natürliche Verbreitungsgrenze nach Osten in die westlichen Gebiete der Ostsee vorgestossene und gut abgewachsene Drepanopsetta-Bestand sich dort nicht vermehren und dauernd festsetzen würde, sondern dass die reichen Jahrgänge 1929 und vor allem 1930 mit beginnender Laichreife aus der Mecklenburger Bucht abwandern würden. Diese Annahme wurde durch Untersuchungen in den letzten beiden Jahren bestätigt (Tabelle 7).

Während also 1934 noch etwa 84 % der gesamten untersuchten Tiere aus Scharbzungen des Jahrganges 1930 bestanden hatten (Tabelle 4), wurden in dem im Juni 1936 untersuchten Fang nur noch 9.6 % dieses einstmals reichen Jahrganges bemerkt. Der ebenfalls reiche Jahrgang 1929, der im März 1933 (Tabelle 3) noch mit 19 %, und im Juni 1934 mit 8 % im Fang vertreten war, war im Juni 1936 gänzlich verschwunden. Dagegen bestand der untersuchte Fang 1936 zu 58.5 % aus dem bisher noch nicht bemerkten Jahrgang 1934, zu etwa 16·8 % aus dem Jahrgang 1933, zu 14·1 % aus dem Jahrgang 1932 und zu 1 % aus dem Jahrgang 1931.

### Tabelle 7.

**Altersgruppenverteilung im Drepanopsetta-Fang aus der Mecklenburger Bucht am 15. Juni 1936.**[1])

♀ (♂)

| Länge cm. | II (1934) | III (1933) | IV (1932) | V (1931) | VI (1930) | Summe |
|---|---|---|---|---|---|---|
| 24 | 14 | 1 | —(1) | — | — | 16 |
| 25 | 22 | 2 | 1 | — | — | 25 |
| 26 | 18 | 4 | 1 | — | 1 | 24 |
| 27 | 8 | 6 | — | — | — | 14 |
| 28 | 3 | 5 | 5 | — | 1 | 14 |
| 29 | — | 2 | — | — | 4 | 6 |
| 30 | — | 1 | 4 | 1 | 1 | 7 |
| 31 | — | — | 3 | — | 4 | 7 |
| 32 | — | — | 1 | — | — | 1 |
| | 65(—) | 21(—) | 15(1) | 1(—) | 11(—) | =114 |
| M: | 25.4 | 26.8 | 28.8 | — | — | 26.63 |
| % | 58.5 | 16.8 | 14.1 | 1.0 | 9.6 | 100 |

[1]) Das Material wurde von Dr. Altnöder, Berlin gesammelt.

lit dem Verschwinden des Jahrganges 1933 zugleich ein starker Rückgang in den Drepaetta-Fängen verbunden (Tabelle 8):

## Tabelle 8.

**panopsetta-Anlandungen verglichen mit den chenfängen nach Material der Warnemünder Fischverwertungsgenossenschaft.**

| at. | Klieschen-anlandungen in kg. | Drepanopsetta-Anlandungen in kg. | proz. Verhältnis von Drepanopsetta-zu Klieschen-anlandungen. |
|---|---|---|---|
| | **a) im Jahre 1935** | | |
| | 4,967 | 701 | 15 % |
| VII | 45,066 | 1,668 | 4 % |
| –IX | 21,303 | 1,062 | 5 % |
| XII | 5,032 | — | 0 % |
| III | 76,368 | 3,431 | 4 % |
| | **b) im Jahre 1936.** | | |
| II | 14,040 | 23 | 0·2 % |
| VIII | 45,304 | 1,894 | 4 % |
| III | 59,344 | 1,917 | 3 % |

Drepanopsetta-Anlandungen in Warnemünde n bei etwa gleichbleibenden Klieschenanngen wie folgt zurück:

| | |
|---|---|
| 1933: | 19,216 kg. |
| 1934: | — |
| 1935: | 3,431 kg. |
| 1936: | 1,916 kg. |

Anlandungen der Scharbzungen hatten also 1933, als der weitaus grösste Teil der Fänge aus Tieren des Jahrganges 1930 bestand, ihren Gipfel erreicht. Bereits im folgenden Jahr wurde — wie uns durch die Warnemünder Fischverwertungsgenossenschaft mitgeteilt wurde — eine starke Abnahme der Drepanopsetta-Anlandungen festgestellt. Leider liegt darüber kein genaues Zahlenmaterial vor. 1935 sanken die Anlandungen schon auf etwa $^1/_6$ und 1936 sogar auf $^1/_9$ der Anlandungen von 1933.

Es leuchtet wohl ein, dass der rapide Rückgang der Drepanopsetta-Fänge nicht allein auf fischereilichen Einfluss zurückgeführt werden kann. Dazu ist er zu gross. Wir müssen vielmehr annehmen, dass die Tiere des Jahrganges 1930 — nachdem sie 1934 zum grössten Teil laichreif geworden waren — die Mecklenburger Bucht verlassen haben und in ihr eigentliches Verbreitungsgebiet zurückgekehrt sind. Der Rückgang der Fänge in den letzten Jahren beweist darüber hinaus, dass seit dem Vorstoss des Jahrganges 1930 noch keine nennenswerte grössere Besiedlung der Mecklenburger Bucht mit jüngeren Jahrgängen erfolgt ist. Es sei denn, dass der als Altersgruppe II im Junifang von 1936 dominierende Jahrgang 1934 sich noch im nächsten Jahr — wenn der ganze Jahrgang zu marktfähigen Grössen herangewachsen ist — als besonders individuenreich erweisen würde.

Zum Schluss sei noch erwähnt, dass auch der im Juni 1936 untersuchte Drepanopsetta-Fang, ebenso wie der im Juni 1934 untersuchte Fang (Tabelle 4), und mehrere andere fast ausschliesslich aus Weibchen bestanden, eine Erscheinung, auf die Strodtmann (12) ebenfalls schon aufmerksam gemacht hat.

# VI.

# SEASONAL GUESTS IN TRANSITION AREA

BY

AAGE J. C. JENSEN

(MS. received March, 1937)

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Abbreviations used:

| | |
|---|---|
| Biol.: | Journals of the Danish Biological Station. |
| C. I. D.: | Card-Index Department of the International Council. |
| FF: | Flora og Fauna, Aarhus. |
| F och F: | Fauna och Flora, Upsala — Stockholm. |
| FT: | Nordisk Tidskrift for Fiskeri, Kjøbenhavn 1874—1882.<br>Fiskeritidende, Randers—København 1883—1891.<br>Dansk Fiskeriforenings Medlemsblad, København 1892—1902.<br>Dansk Fiskeritidende, København 1903—1935. |
| SF: | Svensk Fiskeritidskrift, Upsala—Stockholm 1882—1927.<br>Ny svensk Fiskeritidskrift, Göteborg 1928—1934. |
| Z: | Journals of the Zoological Museum of the University of Copenhagen. |

## I. Introduction.

**he character of the Transition Area.**

Corresponding to the hydrographical character he Transition Area as a boundary area between North Sea and the Baltic, the fauna of the inner is very different from that of the outer one. ying the composition of fish it is characteristic bserve the decrease in number of species as one es south and into the Baltic[1]).

The number of species appearing in the Skage- almost equals that of the North Sea while only t one fourth of these appear in the Baltic er (round Bornholm), in addition, however, to 20, specially Baltic species, that do not reach Skagerak.

n the Skagerak some two thirds of the species be considered stationary*) and more than one th rare visitors from the North Sea or more nt waters.

n the Kattegat about half of the species are nary and two fifths rare visitors, in the Belt- and the western Baltic every other species can onsidered a rare visitor, whilst in the Baltic er the dispersion is somewhat similar to that he Skagerak. — This dispersion is shown in l for the different districts within the Tran- n Area**), but the distinction between the tories must be more or less conditional. A es caught in the inner waters only, such as the *a aquila*, has been put down as a rare visitor ter waters.

1. Möbius and Fr. Heincke: Die Fische der . — Commission zur wissenschaftl. Unters. der deut- Meere in Kiel. Vierter Bericht, 1884—87.

In this paper "stationary" is used to indicate appear- at all seasons, — not in the sense of C. G. Joh. rsen's "Report from the Dan. Biol. Stat." XI, 1902, "which live all their life in our seas." — — The ssion "visitor" indicates a species, not regularly ring in the area, but straying into and staying there nger or shorter periods only.

) Fig. 1. in contribution I of this volume shows the

From Fig. 1 it will be noticed that the number of stationary species is gradually decreasing southwards; the number of regular visitors to the Kattegat almost equals that of the Skagerak but rapidly decreases towards the Baltic proper, whilst the number of rare visitors is fairly high within Kattegat/western Baltic but very low in the Baltic proper — as might be expected on account of the barriers at Drogden and Gedser, where the hydrographical conditions show distinct changes.

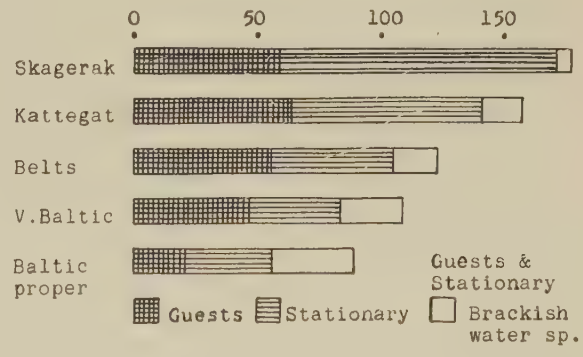



Fig. 1. Approximate number of stationary fish species and of guests from the Ocean, the North Sea or from outer parts of the Transition Area.

That the number of visitors is higher in Kattegat and Belts than in Skagerak is due to the fact that many a species, stationary in the deeper Skagerak waters, appears as visitor to the Kattegat, the Sound and the Belts. Almost all the visitors are seasonal in their appearance. They arrive at all seasons and may be divided according to season.

**b. Causes of fluctuations in the stocks of fish within the area.**

In most cases the variations in hydrographical conditions are the cause of fluctuations in stock or

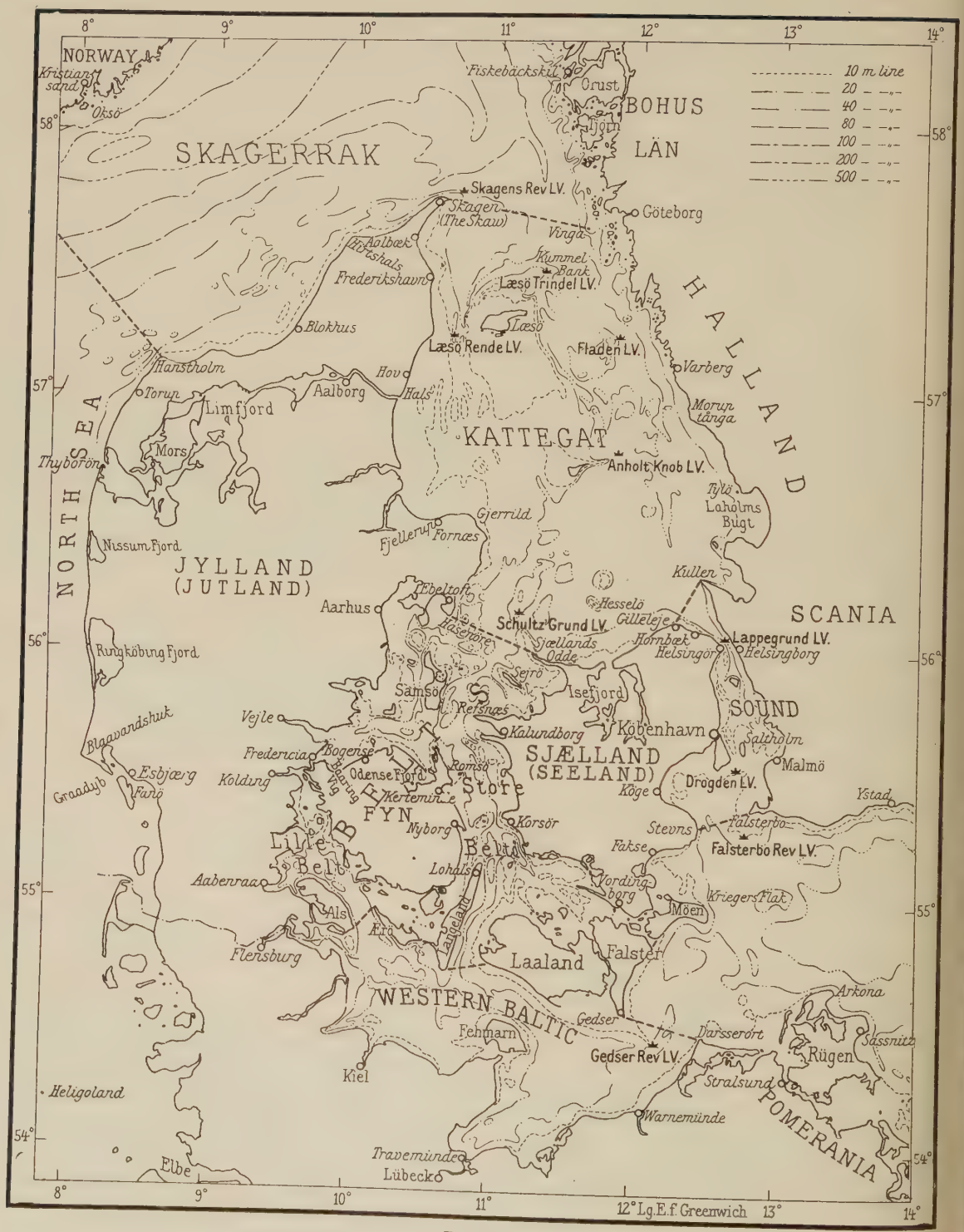

10 m line
20 " "
40 " "
80 " "
100 " "
200 " "
500 " "
NORWAY
SKAGERRAK
BOHUS LÄN
HALLAND
SCANIA
SOUND
KATTEGAT
SJÆLLAND (SEELAND)
FYN
JYLLAND (JUTLAND)
LAALAND
FALSTER
WESTERN BALTIC
POMERANIA
NORTH SEA
Skagens Rev LV.
Læsø Trindel LV.
Læsø Rende LV.
Fladen LV.
Anholt Knob LV.
Schultz Grund LV.
Lappegrund LV.
Drogden LV.
Falsterbo Rev LV.
Gedser Rev LV.
Kullen
Göteborg
Varberg
Aalborg
Aarhus
Esbjærg
Fredericia
Odense Fjord
Kolding
Vejle
Nyborg
Korsör
Slagelse
Kalundborg
København
Helsingör
Helsingborg
Malmö
Köge
Stevns
Falsterbo
Fakse
Gedser
Darsserort
Rügen
Stralsund
Warnemünde
Kiel
Fehmarn
Flensburg
Aabenraa
Als
Ærø
Lolland
Langeland
Gjerrild
Hesselö
Gilleleje
Hornbæk
Sejrö
Samsö
Isefjord
Saltholm
Ystad
Arkona
Sassnitz
Kriegers Flak
Möen
Lübeck
Travemünde
Elbe
Heligoland
Thyborön
Hanstholm
Torup
Limfjord
Mors
Nissum Fjord
Ringkøbing Fjord
Blaavandshuk
Graadyb
Fanø
Skagen (The Skaw)
Frederikshavn
Hirtshals
Aalbæk
Blokhus
Hov
Hals
Fjellerup
Fornæs
Tebeltoft
Hasenøre
Sjællands Odde
Kullen
Tylö
Laholms Bugt
Morup tånga
Kummel Bank
Vinga
Fiskebäckskil
Orust
Tjörn
Oksö
Kristiansand
Bogense
Romsö
Kertemind
Store Belt
Lille Belt
Baring
Lohals
Nordingborg
Gedser
Fehmarn
Sea
Baltic
Pomerania
8°
9°
10°
11°
12°
13°
14°
12° Lg. E. f. Greenwich
54°
55°
56°
57°
58°

Fig. 2.

ibution; but in many cases the actual influence yet unknown. An investigation like the pre- — on covariation between appearance of vi- s and current or other hydrographical con- ns — must in many ways be a hypothetical — and particularly so when the material is e.

ome fluctuations in stocks, though, are in- ndent on hydrographical conditions; thus, the nt of fry of the herring in the inner Tran- n Area is dependent on the size of the stock pawning individuals, thereby determining the of the stock of spawning herrings some years [2]); a stock however that is also dependent on tock of cod which will reduce the former by ng on herring[3]). While the first named of purely biological fluctuations but locally s to play an essential role, the number of ies is undoubtedly a factor to be taken into deration when discussing the causes of fluc- ns in the size of the stocks of fish. The fact fluctuations may be due to the intensity of the ry is well known. —

Ve know that the fluctuations of the total nt of individuals of a species (or race) in cases is determined by the survival.

mong the hydrographical factors influencing urvival the temperature seems to be the most rtant one. Considering stationary species with- e Transition Area, H. B l e g v a d has stated the survival of the cod and the plaice in the ea is strongly influenced by temperature early e year[4]). The temperature especially in the r layer has been somewhat higher in recent , but the corresponding increase in the amount oung plaice[2]) has not asserted itself in the er of the commercial stock due to overfishing. the stock of cod the increase of the tempera- during the months when eggs and pelagic fry und in the water undoubtedly has induced the changes in the size of stock of cod during entury[3]).

he influence of the currents upon the distri- n of eggs and fry and thereby on the secular es in the occurrence of fishes has been in- ated by other authors in this volume (K. A l t- e r, P a u l F r i e d e r i c h M e y e r and . P o u l s e n). In the following pages, I have with the fluctuations in the occurrence of various fish visiting the area in the later stages of their life cycle. Some may be stationary in the area for some few years but most of them are real guests.

It is not all the guests appearing in the Transition Area that have been included in this discussion but preferably those that could elucidate secular fluctuations from occurrence.

As to details of catches I am greatly indebted to Mr. C. A. O t t e r s t r ø m who has kindly placed his collocation and critical studies of older catches at my disposal. My special gratitude is due to Prof. Ad. S. J e n s e n for permission to study the journals of the Zoological Museum and to Dr. H. B l e g v a d for admission to various material collected.

## II. Seasonal appearance and secular fluctuations in the occurrence of the single species.

Seasonal fluctuations in the geographical distribution of fish are primarily determined by temperature because all species require certain intervals of temperature to exist; very few species are definitely stenotherme except during the spawning period. Many fish migrate northward where the temperature of the upper layers increases in summer, and return — or die — when the autumn or winter again cools the water. Other species, such as cod, plaice, and mackerel, escape the low temperatures during winter by emigrating to greater depths, while fish from colder deep-sea areas, such as the Skagerak, appear in more shallow waters during the winter. Also salinity fluctuations may influence fish migrations; thus the late appearance of the porbeagle — late summer or autumn — in the Kattegat and the Belts is very likely due to too low salinity in the spring.

The current as a means of transport must be considered of great importance, since the fact has been established that pelagic swimming fish have no sense of current-direction.[5])

Some species, although stationary, are traced at certain seasons only; this may be due partly to gears catching these species being used during such seasons only, thus most frequently the *Zeugopterus norvegicus*, Gthr. and the *Zeugopterus punctatus* Bl. are by-products from flat-fish catches, but comparatively rare, not only due to a scarce distribution but also to the mesh-width used in this fishery. Records of catches are mostly from seasons of intense fisheries for flat-fish. Another example is the catch of the *Raniceps ranimus* L., rarely recorded

A a g e J. C. J e n s e n: Periodic Fluctuations in the f various Stocks of Fish and their Causes. Medd. f. . f. Danmarks Fiskeri- og Havunders. Ser. Fiskeri, K, No. 5, 1933.

A a g e J. C. J e n s e n: On the Influence of the Size Stock of Cod upon the Yield of the Herring Fishery Kattegat, Belt Sea and Western Baltic, and some Causes of Variations in the Cod and Herring Fishery. dd. f. Komm. f. Havundersøg. Ser. Fiskeri, Bd. VIII, 1929.

H. B l e g v a d: Om gode og daarlige Yngelaar hos og Rødspætter. Dansk Fiskeritidende, 1926, No. 25.

[5]) W. v o n B u d d e n b r o c k: What physiological problems are of interest to the marine biologist in his study of the most important species of fish? (Rapp. & Proc.-Verb. Vol. CI, I, 1, 1936, p. 3).

in summer because it is generally caught by weels, gears but rarely in use during summer.

Also, seasonal records may be due to the biology of the fish, as for instance is the case of the *Trachinus draco* L., a species of no pronounced migratory nature specially caught by seines from June to October; having the habit of digging into the sea-bed it may be assumed that this species, during part of the rest of the year, clings too strongly to the bottom to be catchable by such gears, moreover, the yearly change may be due to changes in areas, where the implements are used, and to less extended seasonal migrations in a south-northern direction. From the research vessels it has been caught at all seasons, but with a very pronounced maximum in September (C. I. D.)[6].

It should be remembered that information from fishermen as to the appearance of rare visitors is but a poor illustration of the seasons in which they exist in the various areas due to changing fisheries in course of the year. This fact undoubtedly assists in reducing the number of visitors recorded during winter, although visitors actually are less common in winter than in summer.

### Seasonal visitors and secular variations in their appearance.

**Winter.**

The mean surface temperature of the Baltic in February varies between 1° and 3° C. with a minimum of about 0.5° C. in bays and fjords. In the lower layers of the Kattegat the February/March temperature is 3.5—4° C., in the western Baltic about 2° C. During summer such temperatures are recorded in deep water and — in upper layers — in Arctic waters only. Few species only belong to the upper Arctic layers and rarely do such species appear in the Transition Area. Collett[7]) records the appearance of the *Mallotus villosus* Müll. in the Oslofjord about 1860 and in May, 1886. The currents, generally, oppose faunistic immigrations from upper Arctic water-layers, direct connexion normally being possible only *via* the East-Icelandic Polar current from which they may arrive into the North Sea through the frequent large Faroe-Shetland Channel whirls. Ad. S. Jensen[8]) has indicated this route as the most likely one followed by a walrus in 1926, but that this route should be followed by fish *en route* for the Transition Area may be considered very exceptional. The capelin recorded in the Oslofjord undoubtedly have travelled along the Norwegian coast, and may be considered exceptions that confirm the rule that the Transition Area is not visited by Artic upper-layer species.

Boreal deep-sea fish, on the other hand, exist more or less stationary in deeper parts of the Skagerak, but existing records are insufficient to determine many species as stationary there. During winter some species occasionally stray further into the Transition Area; some of these migrate regularly to the more shallow waters of the Skagerak and may appear in the Belts and the western Baltic, *viz.*, *Molva vulgaris* Fl. in January—May, *Brosmius brosme* Asc. and *Lophius piscatorius* L. in December—April. Others follow the deeper Eastern Skagerak and go south to the entrance of the Sound, thus: *Phycis blennoides* Brünn. in February, *Sebastes marinus* L. in March—June, *Lepidorhombus whiffiagonis* Walb. in February—May and *Laemargus borealis* M. & H. in February (1906) (Z), whilst other species hardly ever leave the Skagerak and the deep N.E.-Kattegat for more than very short incursions into shallow water or strand dead on the coasts of these areas, *viz.*, *Chimaera monstrosa* L., *Macrurus laevis* Lowe and *Molva byrkelange* Walb. etc. The pelagic, mainly boreal, deep-sea fishes: *Trachypterus arcticus* Brünn. and *Regalecus glesne* Asc. may wash ashore during winter, the former was recorded as far south as the Sound in the autumn of 1860 — the latter has been traced on the Bohuslän coast only.

Some of the species mentioned are of little interest to this report: the ling is more common than the records indicate, so commonly known, actually, by the laity that catches are but rarely reported to Museums, fishery laboratories or to periodicals. In the Skagerak and the northern Kattegat this species is quite common, often it roams about at depths of less than 50 m. and frequently goes astray in the shallow parts of the Kattegat and the Belts without being reported. Similarly the angler may often appear in the Beltsea without being reported. In the western Baltic its appearance will be more frequently reported, but by no means always. A species like the *Lepidorhombus laevis* is, undoubtedly, often overlooked; Sebastes and molva are always frequent in the Skagerak and positive results from examining possible secular variations cannot be expected from existing records of catches near the coasts of Skagerak and Kattegat. On the other hand the appearance of the Norway haddock in the Belts is quite interesting: in May 1930 it was recorded in the Great Belt off Langeland (Biol.).

The appearance of **Laemargus borealis** will very often be recorded and records are therefore of special interest to this survey. The records amount to 10 only, 3 of which at Thy, 1 south of Nissum fjord (1883) near S. Nissum and Hov, — Novbr. 1885 at Torup, Thy, — Jan. 1891 at Thy, — Jan. 1892, 2 specimens at Thy (Z), — Jan. 1893 in the

[6]) Card-Index Department of the International Council.

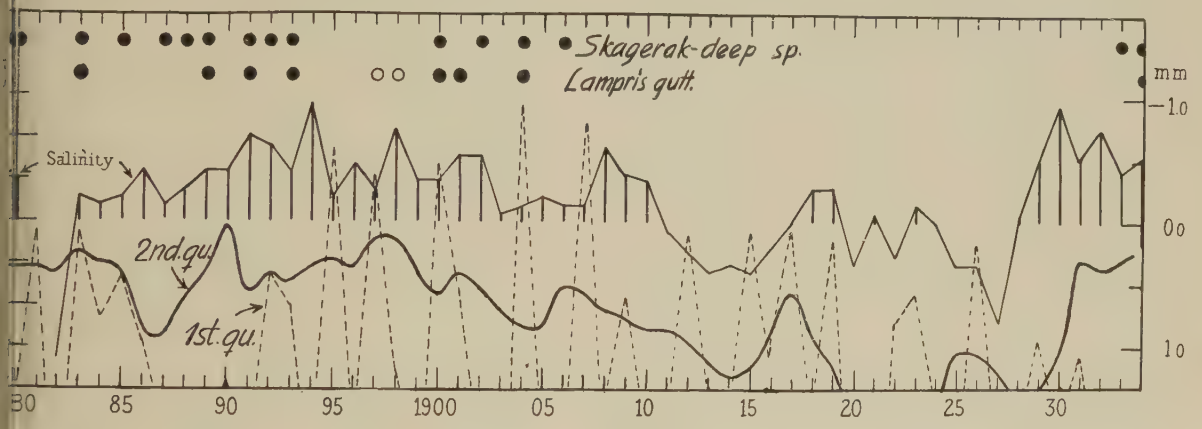
[7]) R. Collett: Meddelelser om Norges Fiske i Aarene 1884—1901. Christiania Vid. Selsk. Forhandl. for 1902, No. 1. 1, Christiania, 1902—05.

[8]) Ad. S. Jensen: Small Contributions to our Knowledge of Danish Fauna. I. Vid. Medd. dansk naturhist. Foren. Bd. 84, 1927.

**Table 1. Monthly means of Temperature, °C.**

| | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| at surface | | | | | | | | | | | | |
| the Skaw ..... | 3·2 | 2·4 | 2·6 | 4·7 | 8·8 | 13·3 | 15·8 | 16·0 | 14·2 | 11·1 | 7·7 | 4·9 |
| Schultz Grund ..... | 2·1 | 1·5 | 2·0 | 4·6 | 9·3 | 14·0 | 16·5 | 16·6 | 14·5 | 11·0 | 7·2 | 4·2 |
| Christiansø ..... | 3·3 | 2·1 | 1·8 | 3·0 | 6·1 | 11·0 | 15·2 | 16·0 | 14·1 | 11·1 | 8·1 | 5·5 |
| Frederikssund*) ..... | 0·6 | 0·5 | 1·9 | 6·0 | 11·9 | 16·4 | 18·3 | 17·3 | 13·9 | 9·2 | 4·7 | 1·7 |
| at bottom | | | | | | | | | | | | |
| the Skaw, 38 m. ..... | 5·0 | 3·9 | 4·1 | 4·8 | 6·8 | 9·4 | 11·9 | 13·8 | 12·9 | 10·9 | 8·5 | 6·6 |
| Schultz Grund, 26 m. ..... | 4·7 | 3·7 | 3·8 | 4·4 | 5·1 | 6·1 | 8·2 | 11·2 | 12·7 | 11·9 | 9·7 | 7·3 |

*) Coastal station (Isefjord inwater-complex).




g. 3. Years in which fishes from deeper parts of the Skagerak are noted further inside the Transition Area n. text), and occurrence of the Kingfish in this area (and at Jæderen, southern Norway: open circles), respectively, mpared with bottom salinity at Anholt Knob in 2nd quarter, and with difference in barometric pressure Fanö—Skaw in the 1st quarter (dotted), and in 2nd quarter (smoothed for 3 years).

næk bay, — Febr. 1906 near Gilleleje (Sjæl- l), — April 1933 at the Skaw, and Jan. 1934 he northern North Sea near the west-coast of and at about 15 m. depth. In the northern North it frequently appears in trawler catches as also fairly frequent in the Skagerak Deep, probably ionary, as according to Collett[7]) it should m the Bundefjord (near Oslo) which is cut off n deep water by a threshold.

t would seem that for the Greenland shark e are distinct secular variations but individually species — as each of the others mentioned — ecorded too scarcely for drawing any conclu- s as to secular variations. Taken *en bloc*, how- the species not excluded above, but excluding wegian records (rather sparce information is to l after 1900), I find one or more individuals ne or more species in 15 years out of the ear period 1880—1906, none are recorded ng 1907—1929, but in 1930, 1933, 1934, 1935 1936 again (cp. Fig. 3).*)

) To the above named species should be added *Anar- as lupus* (common in Kattegat) found at Bornholm 1930 (C. V. Otterstrøm: Nye Bidrag til Born- s Fiskefauna. — Flora og Fauna, Aarhus, 1930, p. 45.)

This secular variation is also noticed in the resulting winds, that may be supposed to have caused a specially strong inflow to the Northern North Sea (and Skagerak) of water from the nether or intermediary layers of the Norwegian Sea. It is also encountered in the secular variations in the occurrence of the kingfish. The probability therefore exists *that the secular variation of inflow, indirectly determined by the wind, causes secular variations in the frequency of the occurrence of boreal deep-sea fish in the Transition Area.*

**Spring.**

Most species immigrating into the Transition Area in spring are such that extend or change their residence to this Area when the temperature reaches a certain limit, and they remain until the temperature goes below this limit (cp. Tab. 1). Such species are mentioned below under heading: Spring — summer — autumn. Among the spring visitors, **Lampris guttatus** Brünn. is remarkable in this area because it is recorded between January and August only, most frequently in June. 18 records are distributed as follows: Jan. — 1, April — 4, May — 2, June — 8, and August — 4. The kingfish

will never be overlooked due to its appearance and size, and records date as far back as the 17th and 18th centuries. Most frequently it is washed ashore but in a few cases it has been caught by line at 100—150 m. depth in the Skagerak. The kingfish occurs in the North Atlantic, in great numbers near Madeira where it is caught at 100—200 m. depths. According to O. Sund it appears in recent years fairly often as a by-product of line catches off Bergen at depths of 170 to 380 m. (autumn and winter) and appears quite frequently at the Bergen market[9]). A single record exists from the Faroes, October 1884 (Z), some near Great Britain and Holland in late summer and autumn and at Iceland late summer, autumn, and winter. Occurrences at Iceland and Norway coincide with the summer maximum of temperature. The kingfish lives in the deeper layers of the "Gulfstream" and seems to move towards NE. in summer, following the extension of the water layers of temperature above 7—8° C.

Most probably the occurrence within the Transition Area is determined by an inflow at the period when the kingfish is retiring from NE.: — in winter and spring an inflow to the North Sea from intermediate layers of the Norwegian Sea must take place during the 1st and 2nd quarters, southern and eastern winds are more frequent than western winds; comparatively great quantities of surface water are thereby carried from the North Sea to the Norwegian Sea and must be compensated by a stronger inflow of nether-layer water. In another paper in this volume I have shown that this inflow must have been stronger between 1880 and 1905, and during the latest quinquennium, than during the intermediate period, due to the influence of wind.

*Secular variations in the occurrence of the kingfish within the Transition Area are characteristical inasmuch as they coincide with the secular variations in inflow.* During the period 1880—1905 records exist from 9 years, next appearance happens in 1934; this cannot be due to a decrease in numbers of the North Atlantic stock in the interval, as the occurrence off Bergen seems to have been fairly constant, and records of individuals washed ashore at Iceland have not decreased[10]). In the Transition Area all occurrences are recorded when preceding months have shown minority of western winds, and during comparatively strong outflow of Baltic water. In the second quarter the pressure-difference: Skaw—Copenhagen, has been exceptionnally low (less than 2 mm.) in 1873, 1883, 1889, 1891 and 1902. In August 1873 the species was recorded near Fiskebäckskil and in Sept. 1873 W. of Lindesnæs[11]), April 1883 near Læsø (F.T.), May 1889 at the Skaw (Z) — and April 1889 in S. Norway[7]) — in 1891 in the Oslofjord[7]). — Further, in June 1893[7]) it was caught in the Oslofjord — a year in which the W.-component of 1st—2nd quarters was about normal, the southern above normal; June 1897 at Soggendal (S. Norway) and in 1898[7]) at Jæderen — in both cases with western winds in spring below normal. In 1900 records exist from the Skaw, June (F.T.), and the Aalbæk bay (Z) — in this year the western wind was weak during 1st quarter, the W.-component in 2nd quarter about normal, the S.-component above normal. Finally a record exists from Gjerrild (F.T.) about the middle of January 1904; the resulting western wind of 4th quarter, 1903, was weak while December, 1903 and first half of January, 1904, showed dominating S. and E. winds.

The record of the Kingfish in April 1934 (Biol.) was made at Frederikshavn; also this case agrees with the theory on the cause of appearance — the autumn of 1933 was characterized by weak western winds, but it should be noted that dominating western winds during 1st quarter, 1934, may have forced this specimen into the Transition Area. an exceptional case, however, among the records mentioned and as such it may be assumed that also this individual has followed the lower current.

Krøyer[12]) states that this species is washed ashore on the north coast of Sjælland mainly after a northern storm and this statement is repeated in later handbooks. *The direction of the wind is obviously determining the coast towards which the body is drifting*, thus, strong eastern winds preceded the 8th of April, 1934, at Frederikshavn while southern and south-eastern winds were dominating in January 1904, prior to the Gjerrild catch; but this obvious fact, of course, can be of no influence as to secular variations in appearance.

Somewhat later in the year the **Centrolophus niger** Gmelin, may appear. It has been recorded from a trawl catch on the Viking Banks in Febr. (1928)[13]), — at Blokhus it has been caught in April 1919[14]), — at Fjellerup, May 1925 (F.T.) and in Baaring Vig in August 1931 (Biol.). This species, it will be remembered, is mainly caught at Genoa but does exist in the Atlantic also. Very likely it has arrived from the "Gulfstream" area of the Atlantic and — like the *Lichia glauca* a. o. — the appearance in the Transition Area has been caused by the increase in strength of this current

[9]) E. Ehrenbaum: Naturgeschichte und Wirtsch. Bedeut. der Seefische Nordeuropas. Handb. der Seefischerei Nordeuropas.

[10]) Cp. B. Sæmundsson: Fiskarnir (Pisces Islandiæ). — Reykjavik 1926. and Zoologiske Meddelelser fra Island. Vid. Medd. dansk naturh. Foren. Bd. 4. 1927.

[11]) W. Lilljeborg: Sveriges och Norges Fiskar. Uppsala 1891.

[12]) Henrik Krøyer: Danmarks Fiske. — Kjøbenhavn 1838—1853.

[13]) Fische der Nord- und Ostsee. Leipzig 1930.

ng — Summer — Autumn.

Various species from rocky coastal areas some-s stray from their home-waters; thus, the rus berggylta sometimes visits the western Katte-the Belts and the western Baltic between April November, the **Crenilabrus mixtus** in June—ember. According to Ehrenbaum[9]) the ner is a frequent guest in the area as far as western Baltic; it is often characterized as a hern species (e.g. Möbius and Heincke[1]), 78) but there is no doubt that it is stationary spawning in Norwegian as well as Swedish ergaards".

Real guests are the **Belone acus** Lisso and the mber scombrus L., two species of importance to fishery; they arrive at the Skagerak and the thern Kattegat about April—May and in the s in May and June and both disappear from the nsition Area about Octbr.—Novbr. Records of le individuals during the winter are exceptional. arrive for purpose of spawning, the latter in E.-Skagerak the former on shallow grounds –2 m.) mainly in the Kattegat but also in the thern part of the Beltsea.

The mackerel requires a temperature of 6°, or e, in the Transition Area, the garfish 5° C. (cp. le 1). A. C. Johansen[15]) states that the rrence of the mackerel is limited during vning by a maximum temperature of about C. As previously shown[16]) *there can be very doubt that indirectly the strength of the out- in Febr./March, and directly the inflow caused by in April determines the immigration of the kerel.* The frequency of eastern winds during -/March has been subject to great variations year to year but no particular secular varia- — apart from one or more 3-year periods — be recorded during the present century. The frequencies of NE., E., and SE.-winds during ./March at the Skaw have been as follows: —09: 40 %, 1910—19: 37 %, 1920—29: 0; and 1930—34: 39 %. No special secular tions are traceable in the corresponding yields fishing unit of the mackerel-fishery in the erak which, however, has been subject to great tions from year to year.

Whilst the immigration from the North Sea seems to take place "against the wind", further ress inside the Skaw occur "for the wind" in surface water layer. Corresponding to very eable secular variations in dominant north- in summer we find great secular variations in yield of the mackerel fishery in the Beltsea, the Sound, and the Baltic proper. Since 1912 the yield can be considered representative of the stock. In spite of an increasing fishing intensity the yield has been steadily decreasing since its culmination in 1913 and 1915—16, — in full agreement with simultaneous variations of the pressure gradient: Fanø — Copenhagen.

The average yield of the Danish mackerel fisheries in the Beltsea, the Sound and the Baltic proper has been arranged below next to difference in tenths of mm. in pressure: Fanø — Copenhagen (the higher positive values denote predominance of N.-component of the wind):

| | yield in metric tons | barometric pressure 2nd quarter | 3rd quarter |
|---|---|---|---|
| 1912—1916 .... | 2182 | 2·6 | 5·3 |
| 1917—1921 .... | 904 | 1·9 | 2·7 |
| 1922—1926 .... | 711 | 1·3 | 1·9 |
| 1927—1931 .... | 762 | —1·0 | —0·9 |
| 1932—1935 .... | 530 | —3·4 | —2·7 |

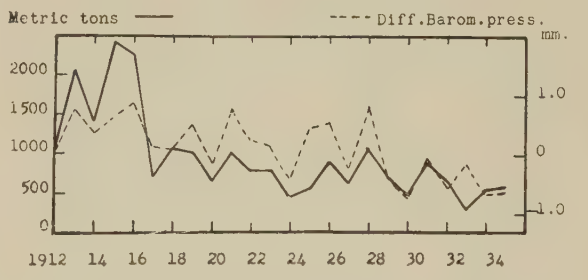



Fig. 4. Yield of the Danish mackerel fishery in the Belt Sea, Sound and Baltic proper compared with difference in barometric pressure Fanø—Copenhagen in the 3rd quarter.

*As to variations from year to year (cp. Fig. 4) as well as secular variations, the yield of the fishery agrees with variations in the N.-component of the wind.* Other physical conditions, however, such as temperature undoubtedly also influence the fishery; it has previously been shown[17]), f. inst., that the yield of the September fishery in the Sound for mackerel is negatively correlated with the temperature of this month. — It is of great interest to record that the mackerel has extended its migrations far into the Baltic during the 25-year period in which its occurrence in the Beltsea was declining. Near Finland one individual was recorded in August, 1923, — one in November, 1925, and one in October, 1929. In October, 1931, in considerable numbers, a few in July—October, 1932, and October, 1933, and during October and November, 1936, again it appeared in considerable numbers (Fiskeritidskr. for Finland). Probably dominating western winds in recent years have caused this.

) Ad. S. Jensen: Smaa Bidrag til dansk Faunistik. edd. dansk naturhistorisk Forening. Bd. 72, p. 91.
) A. C. Johansen: On the influence of the currents — Medd. f. Komm. f. Havundersøg. Ser. Fiskeri. Bd. No. 8, 1925.
) Aage J. C. Jensen: Utsigterna för Makrillfisket ttegat—Skagerack 1933. — Ny svensk Fiskeritidskrift, p. 128.

[17]) Aage J. C. Jensen: On the Influence of hydrographical factors upon the yield of the mackerel fishery in the Sound. — Rep. Dan. Biol. Stat., XXXVI, 1930.

No more is it possible for the garfish, to analyze in detail in this short paper the — probably very complicated — influence of hydrographic-meteorologic conditions. Survival of fry seems to be of greater influence as to yield of the garfish fishery than is the case with the mackerel. The yield seems positively correlated with the water temperature of April—May, in such manner that a positive correlation exists between temperatures in these months in one year and the yield 2—4 years later, when the garfish has reached a length of 50 cm. or more. Investigations seem to show that fairly quiet wind-conditions in the 2nd quarter are necessary for good survival. In Tab. 2, a comparison has been arranged, between years of positive surface temperature-anomalies in the 2nd quarter (at Schultz Grund) and yields above average of the Danish Beltsea fishery. This comparison seems to support the theory on agreement between yields and hypothetical survival years.

**Table 2.**

| Years, when the Temperature of 2nd quarter has been above 9.5 ° C. | | Yield of fishery in the Belt Sea above 250 metric tons | |
|---|---|---|---|
| Year | C °. | Year | metric tons |
| 1906 | 10·0 | 1908 | 259 |
| | | 1909 | 289 |
| 1910 | 10·2 | 1912 | 653 |
| 1911 | 9·8 | 1913 | 399 |
| | | 1914 | 293 |
| 1913 | 9·5 | | |
| 1914*) | 10·2 | 1916 | 275 |
| 1918 | 9·6 | | |
| 1919*) | 9·7 | | |
| 1920*) | 10·0 | | |
| 1921*) | 11·0 | | |
| 1925 | 10·5 | 1927 | 320 |
| 1926 | 9·9 | 1928 | 502 |
| | | 1929 | 445 |
| | | 1932 | 253 |
| 1930 | 10·5 | 1933 | 261 |
| | | 1934 | 393 |
| 1933 | 10·5 | 1935 | 396 |

*) Years with especially strong western winds in 2nd quarter.

The **Trigla gurnardus** L. appears during the same season; undoubtedly some have spent the winter in the deeper layers of the Kattegat and the Skagerak, but the majority will be immigrating from the North Sea. Maximum of occurrence in the Transition Area happens in autumn. Its arrival is followed by the *Trigla hirunda* Bloch, the *T. pini* Bloch and the *T. lineata* L. Every year the grey gurnard is recorded in the Beltsea in single specimens while its appearance in the Kattegat is regular; also the *T. hirundo* is regularly recorded in the Skagerak.

Gurnards have been marketed at Göteborg especially since 1928, and are caught at all seasons (maximum in March). The fluctuations during these years have been the same as those of the western winds in 2nd and 3rd quarters.

Judging from catches of research vessels (C. I. D.)[6]) other factors may regulate the occurrence in the southern Kattegat and the Belts.

Southern species such as **Sombresox saurus** Walb. and the **Caranx trachurus** L. arrive in early summer, the former being recorded in May/June and October/November. C. V. Otterstrøm[18]) states that this broken record very likely is due to catches mainly being made by pound nets, gears rarely used in summer. Since 1880, it has been recorded: in 1881 and 1884, at Strömstad in Bohuslän, — Nov. 1893 (Z) in the Great Belt, — June 1892 (Z) at Refsnæs, — May 1893 (Z) on the Copenhagen market, and in 1909 from which year we have several records: in Nov. at Humlebæk and Snekkersten (Z), in the Sejrø bay, where no less than 150 individuals were washed ashore after a storm[18]), and at Eckernföhrde in Oct.[13]). Since then it has been recorded from Baaring Vig only in June 1916 (Z). — These records are very irregular but occurrences have probably been much more frequent.

As to causes of these variations nothing can be said.

The horse-mackerel in the Atlantic and the North Sea is traced down to depths of 100 m. or more; young fish are frequently recorded from the Oslofjord, now and then in the Beltsea. It appears in the Skagerak, the Kattegat and the Sound from March/April to December, in the Beltsea in late summer and autumn.

During November it has been recorded in the Baltic proper by the S/S Skagerak (1914 — C. I. D.)[6]) and at Aarsdale, Bornholm, (1933 — Biol.). Since 1919, — a period with many years of exceptionally strong winds from N. and NW. (pressure gradient Fanø—Skaw) in 2nd and 3rd quarters, very few catches have been reported, and if so, in years only of the lowest gradient (1920, 1922, 1924 and 1930). Also prior to 1919, it seems rarely recorded under similar conditions. *These facts suggest that this species* — like certain other ones belonging to the deeper layers — *immigrates with the lower current.*

Variations in the occurrence of *Rhina squatina* L., *Trygon pastinaca* L., *Torpedo marmorata* Risso, *Torpedo hebetans* Lowe and *Myliobatis aquila* L. do not seem to be referable to wind or current; the latter three have been known in the Transition Area during recent years only, the former two show varying fluctuations, with catches mainly concentrated — in numbers — prior to 1890, about 1905 and since 1920.

The **Sarda pelamis** Brünn. may visit the Transition Area in June/September when the upper layer

[18]) C. V. Otterstrøm: Danmarks Fauna, Fisk I—III, 1912—17, København.

peratures rise above some 14°. The occurrence trictly limited as will appear from the following ords:

| | June | July | Aug. | Sept. | ... Jan. |
|---|---|---|---|---|---|
| gerak—Kattegat . | 6 | 5 | 3 | 1 | 1 |
| sea—Sound .... | 2 | — | 3 | 4 | — |

Undoubtedly a real phase-displacement exists ween Skagerak/Kattegat and Sound/Beltsea and be explained by lower salinities in spring. The rrence shows a distinct secular variation: since ) it has been recorded from the S. Kattegat and Beltsea in Sept. 1901 and in 6 years only out he period 1912—1928; undoubtedly occurrences been due to strong W. and NW.-winds in these rs. Other large scombrides visiting the Trans- Area are *Thunnus thynnus* L., *Euthynnus eratus* Raf., *Auxis rockeii* Risso, and *Orcynopsis olor* Geoffr. The latter three are not always rmined as to species but simply recorded as nit", which designation sometimes may include *Sarda pelamis*.

The **tunny** is seen between June and Novem- 9) but in several cases those recorded during ber/November have been dead or dying. ording to "Zoologica Danica" (Ad. S. Jen- ) it was a frequent visitor — single or in small als — by the end of the last century.

Collett states that in 1860—80 numerous viduals were recorded from Lindesnæs to Oslo-fjord, whilst in 1880—1900 it was comparatively scarce although recorded every year[7]).

At the beginning of this century it seems to have been fairly scarce; the three records are: Warnemünde 1903[13]), at Liseleje Oct. 1905[18]) and at Strømstad Aug. 1907 (SF).

Since 1912 or 1913 it occurred more frequently in the Skagerak; according to "Ny Svensk Fiskeritidskrift" it appeared in great numbers from July to Sept. and was subject to fishery from steamers; it has been recorded in the North Sea by the English fishery staff since 1912[20]). Dr. C. G. Joh. Petersen has informed C. V. Otterstrøm that several shoals of tunnies were observed by him during Aug. 1913 in the Kattegat, the size being about 1 m. According to "Dansk Fiskeritidende" it was very numerous in the autumn of 1915. The tunny fishery from the Odden harbour commenced about then. In Sept. 1921 the tunny was caught at the Skaw ("Dansk Fiskeritidende"), in the autumn 1922 several times near Hals (Gregersen in "Flora og Fauna"). In the following years it was frequently observed in the Kattegat and in 1926 the "Tunny-sport" was started from Sjællands Odde.

According to Wolfe-Murray[21]) it was common in the North Sea in 1922, occurred in the greatest number in 1923, in considerable number in 1924—1925, but since then decreasingly until in 1931 it was fairly scarce. According to le Gall[22]) it appeared in greater numbers in 1928 than in preceding years. In the Kattegat it was often caught north of Sjælland and near Ebeltoft in 1928, in 1929 in great numbers near Anholt during the herring fishery — record catch by a single boat being 38 ind. of 50—75 kg. in one day. In 1926—1927 few specimens only were caught.

According to Danish fishery statistics and information by L. Svendsen the following yields are on record:

| | Sjællands Odde | Skaw | Esbjerg | Thyborøn |
|---|---|---|---|---|
| 1928 (L. S.) | about 90 ind. | about 200 ind. (Anholt) | ? | ? |
| 1929 (L. S.) | „ 100 „ | ? | ? | ? |
| 1930 | „ 50 „ | a few | a few | ? |
| 1931 | „ 60 „ | 17000 kg. | a few | |
| 1932 | „ 200 „ | 18000 „ | 75000 kg. | |
| 1933 | „ 50 „ | 1000 „ | 30000 „ | |
| 1934 | „ 25 „ | 5000 „ | 13000 „ | |
| 1935 | „ 35 „ | 4300 „ | 21000 „ | 120 ind. |
| 1936 | „ 27 „ | 4265 „ | about 34000 „ | 607 „ |

[9]) One specimen has been taken on April 24th, 1787, nekkersten. — Vid. Selsk. Skr., Ny Samling, III. p. 406.
[20]) E. S. Russell, Journal du Cons. Vol. VII, Foot- p. 252.
[21]) D. K. Wolfe Murray. Tunny *(Thunnus thynnus* in the North Sea. — Journal du Cons., Vol. VII. p. 251,
[22]) J. le Gall: Thon et Germon. — Revue des Travaux e II. Fasc. III. Paris 1929.

According to Rosén[23]) the quantities landed at Gøteborg were:

| | | | |
|---|---|---|---|
| 1913 | 439 indiv. | 1925 | 150 kg. |
| 1914 | 132 „ | 1926 | 0 |
| 1915 | 7854 „ | 1927 | 0 |
| 1916 | 1942 „ | 1928 | 1 indiv. |
| 1917 | 1 „ | 1929 | 8040 kg. |
| 1918 | 327 „ | 1930 | 448 „ |
| 1919 | 3740 „ | 1931 | 2507 „ |
| 1920 | 0 „ | 1932 | 4950 „ |
| 1921 | 18 „ | 1933 | 7150 „ |
| 1922 | 9 „ | 1934 | 6113 „ |
| 1923 | 1 „ | | |
| 1924 | 1 „ | | |

That the tunny stock in southern waters is subject to great variations is unquestionable[24]), and this of course influences the occurrence in more northerly waters. But *there can be hardly any doubt as to the frequency of appearance being dependable on frequency of western winds.* In the North Sea it has appeared more frequently since W.-winds (pressure gradient Fanø—Skaw or Copenhagen—Skaw) have been dominant in 2nd quarter, viz., since about 1920; its appearance since 1912 agrees with the fact that W.-winds have been increasing since that year. Large catches in 1928—29 and in 1931—32 in the Kattegat correspond to exceptionally high simultaneous pressure gradients Fanø—Skaw during 3rd quarter (cp. Fig. 5) as also the culminations of the Swedish Fishery, 1915 & 1919, correspond to maxima of this gradient. After recommencing the tunny-fishery in 1929, the Swedish yield follows the variations of this pressure gradient astonishing well.

In the Mediterranean and the Bay of Biscay the tunny is generally considered stenohaline and to avoid salinities below 35 ‰. In the Transition Area it is rarely recorded south of Sjællands Odde (sometimes from the Great Belt off Nyborg) or the northernmost part of the Sound. In these parts the tunny encounters surface salinities of about 18 ‰, 20 ‰ at 5 m. depth, and 25—30 ‰ in lower layers. Probably the occurrence is influenced also by depth. N. of the above-mentioned geographical limits, wide areas are 30 m. deep or more while such depths exist in narrow channels through the Belts only. Single specimens may stray into the brackish Baltic water — even as far as Stralsund where one individual was caught in 1869[13]) in a salinity of about 8 ‰.

As to other large *Scombridae* the **Euthynnus alliteratus** was encountered during July—October in the Skagerak and the eastern Kattegat as far as the Sound in 1857, 1878, 1881, 1892, 1907, 1909 and 1930; the **Euthynnus pelamis** during August—October near Bohuslän, at Varberg, and at Nyrup bay in NW. Sjælland; four records only seem to exist: 1873, 1875, about 1892 and 1922. The **Auxis rockeii** has been caught in the Skagerak during Sept. 1887, 1890 and 1901. These species have undoubtedly appeared more frequently than recorded, but have been simply recorded as "tunnies" by fishermen.

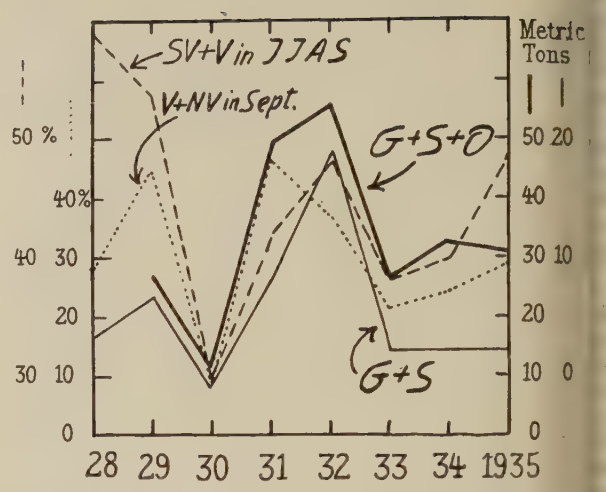



Fig. 5. Yield of the tunny fishery from Göteborg (G), Skaw (S) and Sjællands Odde (O) compared with frequency of western winds.

The pronounced deep sea scombrid **Orcynopsis unicolor** has been only twice recorded — in 1876 — in the NE.-Skagerak.

The *Sarda pelamis* and *Euthynnus pelamis* seem to follow the secular variations of the tunny, while the other species probably visit the Transition Area after periods of comparatively light western winds, e.g., with the lower current, but as to secular variations nothing can be stated definitely, due to insufficient records of these species.

**Mullus surmuletus** Rond. is a pronounced summer visitor, it being recorded preferably from July to October in the Kattegat, from August to October in the Beltsea, and in the W. Baltic during Sept.—Oct. Thus, it seems to emigrate with temperatures of about 10° C., but Krøyer states that one specimen was caught in the Sound, March 1834, and the Zoologisk Museum's Journal records a catch at Frederikshavn, March 1900, as also the Svensk Fiskeritidende mentions a catch in January 1902 at Bohuslän. — The winter of 1900 was exceptionally cold, that of 1902 about average. As against these three records, individuals are on record between July and October in 14 years.

[23]) For the years 1913—24 from L. A. Jägerskiöld: Sydliga gäster vid våra kuster. — Naturens Liv (Reprint without printing year), for the later years from Årsbok, Göteborgs och Bohusläns Havfiskeförening utarbetad av Nils Rosén.

[24]) A. E. Neuparth: Note sur les fluctuations de la pêche de Thon (Thunnus thynnus L.) sur la côte Sud du Portugal. — Rapp. et Proc.-Verb. Vol. XXXV. 1925.

lagic eggs of the mullet have been found in the uthern North Sea, and young fish at the bottom- ge along the coast of Skagerak and Northern ttegat. It may, therefore, from time to time main stationary in the Transition Area.

The occurrence of this species seems generally ited to periods of comparatively slight W.-winds ring 2nd and 3rd quarters, and thus be carried o the Transition Area by the lower current. The cks along the British coasts, however, may also luence the fluctuations of its appearance on this e of the North Sea. Ehrenbaum states that red mullet appears in the North Sea with strong stern winds[9]).

**Lichia glauca** L. seems recorded three times y: at Korsør — Sept. 1918 (Ad. S. Jen- n)[14]) at Hals — August 1920 (ibid), and in Aalbæk bay 1932 (Biol); it belongs to species own during the last 20 years only and occur- ces are explainable by dominant SW-winds and s thus carried by the increased inflow of "Gulf eam" water into the North Sea.

**mmer and Autumn.**

Arrivals of some southern fish, spawning in ckish water: the grey mullet and the bass, to the gerak and northern Kattegat, begin in spring, culminate in September soon after which month emigration commences. For the **Mugil chelo** y. the following records exist:

| | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Skagerak—Kattegat*) .... | — | 1 | 2 | 2 | 1 | 2 | 4 | + | + | — | — |
| Belt—Sound ..... | 1 | — | — | 1 | 1 | 4 | 3 | — | — | — | 1 |
| Western Baltic ..... | — | — | — | — | — | 1 | 1 | 2 | 1 | — | — |

*) + denotes occurrence stated, but numbers unknown, + + in following tables denotes relatively frequent occurrences.

For this species, thus, considerable phase-dis- cements in occurrence exist between different as. By the end of the last century it was fairly mon in South Norwegian waters and Collett gests that this appearance was caused by an nigrated stationary shoal. The occurrence of species does not seem connectable with hydro- hical conditions and definite secular variations not be formed from the records.

**Mugil capito** Cuv. and **M. auratus** Risso also visitors to the Transition Area but arrive later the year; specially they are recorded in years n the grey mullet appears.

The **Labrax lupus** Cuv. has been recorded as ows:

| | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|
| gerak/Kattegat .... | 1? | 3 | 2 | 1 | 0 | 6 | 3 | 2 |
| sea/Sound ..... | — | — | — | 2 | 2 | 4 | 2 | — |
| fjord ..... | — | — | — | 3 | 2 | 4 | 1 | — |

Occurrence in inner waters is limited to summer and autumn, i.e., to periods when approaching the coast for spawning.

No more for this species than for other brakish-water spawning fish, the *Mugilidae*, pronounced secular variations can be shown; in certain years conditions in fjords and partly closed areas such as the Limfjord seem favourable for spawning, but no particular relation seems present to hydrographical variations. It is noteworthy, however, that the bass was exceptionally rich near Hals in 1923 when the spring-inflow was very strong, a year in which the *Mugil capito* reached as far into the Baltic as Finland.

Several species arrive at the Transition Area about July/August and remain till the end of the calendar year. **Lamna cornubica** Gmelin is one of the southern North Sea stationary species which in winter moves north to deeper waters. It generally lives in lower water layers, but can be encountered in upper layers also — chasing the herring shoals. During 3rd and 4th quarter it is a regular visitor to the lower layers of Kattegat — as far south as Anholt. In recent years Norwegian and Swedish fishermen have searched this stock in the Kattegat and the Skagerak, and have utilized it profitably[25]). Evidently it is a rarer visitor to the upper layer of the Kattegat than in the North Sea and undoubtedly it is the low salinity which limits the appearance of this species as well as other selachians. Probably also it is the low spring salinity in the upper layer which causes absence of records from the Kattegat before June. When washed ashore in the southern Kattegat or the Beltsea it is generally described by fishermen (and the press) as Blaahaj ("blue shark"), Menneskeæderhaj ("man eating") or Havkal ("Greenland shark"). Records of its appearance in the Beltsea are too scanty to allow any conclusion as to secular variations.

**Zeus faber** L. is a stationary species in the Skagerak but is caught in the Kattegat, the Beltsea and the Sound also during August/December, most frequently by Danish seine or otter seines, catches which very likely give an incorrect picture of occurrence as this gear is very little used in deeper water during spring and early summer; immigration, therefore, may take place earlier.

The literature searched gives the following records of appearance:

[25]) N. Rosén: Bohuslänsk fiske efter Sillhaj (Håbrand). — Ny Svensk Fiskeritidskrift. Göteborg 1933, p. 19.

| | Skagerak | Kattegat | Sound/Belt |
|---|---|---|---|
| February | 2 | — | — |
| March | — | — | — |
| April | 2 | — | — |
| May | 1 | — | — |
| June | 3 | — | — |
| July | 1 | — | — |
| August | 6 | 3 | — |
| September | 1 | 3 | 1 |
| October | 2 | 4 | 1 |
| November | 3 | 2 | — |
| December | — | 2 | — |
| January | 1 | 1 | 1 |

In the Skagerak it has been recorded more frequently during this century than before, but Jägerskiöld is very likely correct in stating that this may be due to the increased use of trawl and Danish seine[23]).

Also in the Kattegat and the Beltsea the seine fishery has been intensified but here no increase in catches is noticeable.

An examination of the years shows that appearance in the South-Eastern Skagerak, the Kattegat and the Beltsea correspond to years of slight W-winds in 2nd and 3rd quarter, *viz.*, periods of strong inflow in the lower layer (Fig. 2).

During the period of slight western winds 1896—1916, especially in the third quarter, the John dory has been recorded in the Kattegat or the Belt sea in 6 years. Later on it was found: — in 1925 at Hals in the summer (F F), and off Hornbæk in August (F T); this year the eastern winds predominated during July; — in 1927 af Fornæs in August (Z); westerly winds had predominated during July—August but their force had been about ½ Beauforts only, while eastern and south-eastern winds had blown with greater force in periods; — in 1928 at Refsnæs in January (Biol.). The 4th quarter of 1927 had shown unusually slight resulting western winds; — in 1935 at Læsø in Nov. (Biol.), in Kalundborg Fjord in Dec. (letter from Mr. J. P. C. Jarlund) and 1936 at Gilleleje in January. In November and December of 1935 easterly winds were markedly predominating.

The swordfish (**Xiphias gladius** L.) has been recorded between July and February only and is rarely observed in the Skagerak or Kattegat, more often in the Beltsea, the Sound and the Baltic. The records traced are:

| | July | August | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. |
|---|---|---|---|---|---|---|---|---|
| Skagerak/Kattegat | + | ++ | 2 | 1 | + | — | — | — |
| Sound/Belts | 1 | 2 | 4 | 1 | — | — | — | — |
| Baltic*) | — | 1 | 2 | 8 | 2 | 1 | — | 1 |

*) Including southern part of the Little Belt.

Duncker[26]) explains the appearance in the western Baltic by the species' preference for deep water, and this agrees with but few observations from the Skagerak and Kattegat. Also, secular variations in occurrence support this theory inasmuch as records generally succeed periods of but slight W.-winds, *viz.*, periods of strong inflow in the lower layer, caused by increased outflow in upper layer.

**Pagellus centrodontus** de la Roche may be encountered in the Skagerak at all seasons but apparently it does not spawn in that area. It seems to keep to the lower layer preferably and in agreement herewith to show a tendency — although but little pronounced — towards secular variations covarying with light western winds.

All summer and autumn guests discussed above seem to prefer the lower water layers and judging from secular variations they seem to "face the wind" when immigrating. Southern sharks visiting these waters, however, seem to go "for the wind"; records of such are: the **Scylliorhinus Stellaris** L. (Nov. 1876), **Carcharias glaucus** L. (Nov. 1883) and **Alopias vulpes** Gmelin in 1878, Dec. 1886. Oct. 1917, Nov. 1917, July 1928 and Oct. 1933.

Also the **Mola mola** L. appears between August and January, maximum of frequency, however, occurring somewhat later:

| | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. |
|---|---|---|---|---|---|---|
| Skagerak/N. Kattegat | 5 | 3 | 5 | 10 | 8 | — |
| S. Kattegat | — | — | 1 | 6 | 2 | — |
| Sound | — | — | 1 | 3 | — | — |
| Belts | — | 1 | 4 | 5 | 1 | 1 |
| W. Baltic*) | — | — | 2 | — | — | — |

*) including S. Little Belt.

For this species as for the *Brama rayi* (mentioned below) it is characteristic that a rather short phase-displacement, only, seems to exist between appearances in outer and inner Transition Area. This phase-displacement is less than expected according to the average strength of current. No doubt it is due to the fact that individuals coming to the inner parts of Transition Area in the winter time die when the water is cooled. A. C. Johansen[27]) has thoroughly studied this species in north-western Europe, and has shown a phase-displacement of about 4 months between its appearance near the coasts of Great Britain and of Denmark. He regards this species as a giant plankton which is carried passively by the inflowing Atlantic water and which reaches Denmark when this inflow — as shown by Pettersson — reaches maximum in the autumn.

From the foregoing it seems apparent that also a large number of other fish will follow the currents.

[26]) D. G. Duncker: Der Schwertfisch (*Xiphias gladius* L.) an den Küsten von Schleswig—Holstein. — Die Heimat. Kiel. 1927 (Fische der Nord- u. Ostsee).

[27]) A. C. Johansen: Vid. Medd. dansk naturh. Forening. Bd. 67. p. VI. 1916.

A peculiar species like the sunfish seems to be ralyzed by low temperatures and rarely survive nperatures lower than 7—8° C; this species will y rarely escape observation.

One of these records is of special biological erest: at Faxebay in 1932 one was caught; its ght was 12·2 kg., its height — fins included — cm.; it was caught by poundnet on October 22nd water af 9 ‰ salinity and a temperature of ° C.[28]). It lived in the well for a couple of s and was very lively — both when being caught l in the well, and the sunfish thus seems able exist in low salinities. It has undoubtedly been ried across the Drogden-threshold by an ow of 15—19 ‰ water with a temperature of ut 10·5° C. recorded after Oct. 16th, — gene- y speaking the sunfish — like the tunny — is ely recorded alive in salinities below 20 ‰ temperatures below 8° C.

Inside the Skaw it has been recorded as ows[29]):

| Period | Sunfish observed | | Mean-difference (tenths of mm.) Fanø—Skaw*) | | |
|---|---|---|---|---|---|
| | No. of years | Individuals | | 2nd quarter | 3rd quarter |
| 1870—79 | 4 | 5 | (1873—79) | 7 | 12 |
| 1880—89 | 1 | 1 | | 4 | 12 |
| 1890—99 | 1 | 1 | | 3 | 18 |
| 1900—09 | 3 | 5 | | 7 | 21 |
| 1910—19 | 6 | 10 | | 10 | 22 |
| 1920—29 | 4 | 9 | | 18 | 31 |
| 1930—36 | 5 | 10 | (1930—34) | 11 | 23 |

) During later years the heavy southern component of wind has contributed to the strengthening of the flow tlantic water into the North Sea.

Thus, this species seems to have become increa- ly common in the Transition Area during this ury, a fact that may be due to the increase of ng western summer winds, causing an increased -going water movement in the Atlantic.

Occurrences in the southern Kattegat are with- doubt due to strong W.-winds, causing eased inflow of surface water.

The **Engraulis encrasicholus** L. and the **Clupea hardus** Walb. may appear in the Transition n from April/May to early winter; the sardine been recorded once in February even. — Both ies show considerable phase-displacements ween appearance in outer and inner waters. In Baltic, summer and autumn seems the only od of occurrence. The secular variations of occurrence seem characterized by richer catches from 1865/70 to about 1885, since then occasional catches in single years only until 1934 when the anchovy again became more common.

Since 1870, the anchovy is known at Saltholm, June 1870,[18]) — the Skaw 1879 — Travemünde, about 1879[18]), — Bogense (E. of Baaring Vig), June (Z) and July (FT) 1885, — Nyborg, June (Z), — Baaring Vig (Autumn) and Køge Bay (Z) Aug. 1903, — Korsør, June 1918 (FT), — Hals, July 1923 (FF), — Bornholm S.E., Nov. 1934 (Biol.), — Kalundborg, autumn 1935[31]), and E. of Bornholm, Oct. 1935 (Biol.), — Lohals, June 1936 (Biol.) and Vejlefjord, Oct. 1936 (Biol.).

The sardine was recorded at Strømstad, July (DF), and Baaring Vig, autumn (FT) 1884, possibly Little Belt June 1885 (FT) (this record of "Thousands" is considered doubtful by C. V. Otterstrøm), Christiansø, Nov. 1886 (Z), — Vordingborg, Nov. 1886 (Z), — Snekkersten, Febr. 1887 (Z), — Vordingborg, May 1887 (Z), — Nexelø bay, Aug. 1904 (FT), — Hals, Sept. 1930 (FF).

Being pronounced surface species, variations in occurrence seem directly influenced by the wind, strong SW.-winds being favourable for this immigration.

The **Brama rayi** Bloch has been recorded as follows:

| | Sept. | Oct. | Nov. | Dec. | winter |
|---|---|---|---|---|---|
| Skagerak/N. Kattegat .. | 1*) | 1 | 8 | 4 | — |
| S. Kattegat ..... | 2 | 1 | 4 | 2 | 1 |
| Belts ..... | — | 1 | 3 | — | — |
| Sound ..... | — | 1 | 2 | 3 | 4 |
| Baltic proper ..... | 1*) | — | — | — | — |

*) Autumn.

Evidently there is but little difference in season of appearance in outer and inner waters. The species is limited by temperature and hardly anyone of those reaching the inner Transition Area is able to return. The Ray's bream is a pronounced deep sea fish, living at 50—100 m. and more. According to le Gall[32]) it belongs at depths between 400—900 m., appearing in higher layers in summer, however, during spawning.

Since 1870 it has been recorded within the Transition Area as follows: 1876 at the Skaw, — 1893, 1895—97 (Z) and in 1921, 22, 1924—29, 1931, 1933 and 1934. It is characteristic of distributions that it has never been recorded at the Norwegian Skagerak coast; but at Bohuslän, W.-coast of Jutland (north of Ringkøbing), round the Skaw and Kattegat coasts, some in the Sound and Belts and a single individual at the Pommeranian coast. Comparatively few records from the Halland

[8]) Observations are made every day from the Danish orological Institute at Rødvig in Faxebay.

[9]) Compilation from records given by Biol., FF, F och T, SF, Z and by Collett[7]), Jägerskiöld[23]) and C. Jarlund (letter to the author) and C. G. Joh. ersen[30]).

[0]) C. G. Joh. Petersen: Nye Bidrag til den danske iskefauna. — Vid. Medd. dansk Naturh. Foren. Bd. 66. -87.

[31]) J. P. C. Jarlund in letter to the author.

[32]) Faune Ichthyologique. — Cons. Perm. Int. 1933. Copenhague.

coast may be due to its rocky nature, where people do not live close to the shore and where fishes washed ashore easily escape observation.

This distribution no doubt is due to the fact that it very likely perishes when led astray to the southern shallow part of the Skagerak, while fishes in the northern part may seek deeper water. Within the Kattegat it probably travels in upper as well as lower layers — in South very likely in the lower one. Apart from the Pommeranian record (autumn 1826) it seems to travel with water of about 20 $^0/_{00}$ salinity.

Krøyer[12]) states that it is washed ashore after a storm, but doubts the record of one supposed to be washed ashore on the north coast of Sjælland after an east storm. Some records have succeeded storms, *viz.*, near Romsø on Nov. 13th 1922 after strong SE.-winds (force 7), succeeding strong wind from the south (force 9) and WSW. (force 8) at the beginning of November.

In 1925 several specimens were found in the Sound, at the Skaw and at Bohuslän in Nov./Dec., but the early Oct. only records NW.-wind, force 7—8, whilst November several times records ESE., 7 and ENE., 8—10. Thus, stranding may happen after eastern winds and the occurrence can be explained by travelling in the lower current. In other cased it has been washed ashore during quiet periods, thus, on Dec. 6th, 1934, at Aalsgaarde, S. of Elsinore, in the northern part of the Sound,

| | July | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | March | Apr. | May | June |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skagerak | + | ++ | ++ | ++ | + | + | + | + | + | + | + | + |
| Kattegat | — | — | 1 | — | — | 1 | 2 | 1 | — | — | — | — |
| Sound—Belts | — | — | — | — | 1 | 1 | 6 | 1 | 1 | — | — | — |
| Western Baltic | — | — | — | — | — | 1 | 1 | — | — | 1 | — | — |

it was still alive when washed ashore. Wind had been W. and NW., 1—2, until on Nov. 18th it increased and was then eastern. The salinity was low but on Dec. 1st and 2nd salinities above 20 $^0/_{00}$ had been recorded even at surface; the temperature of the upper layer 7·5—8° C. and 9—10° C. in the lower one. In recent years the number caught has been steadily increasing, due also to gears being fixed in increased numbers and at greater length from the coast, as far as the 10 m. contour even.

Occurrence happens in series of years when southern and western winds have dominated in summer and when specially strong inflows of "Gulf stream" water must have taken place N. of Scotland to the North Sea. In 1927 it appeared exceptionally numerous in the Transition Area, as well as in Scottish and NE.-English waters, i.e., in a year when the W.-component of the wind was extraordinarily powerful.

Some of the summer visitors may pass the winter in the deeper parts of the Transition Area and thus in some years they may be considered stationary. Whether such species as the **Merluccius vulgaris** Flem. and the **Gadus luscus** L. have been stationary inside the Skagerak has not been proved — possibly though in the Northern Kattegat. Ahrensberg[33]) states that the stock of hake during the year 1824—1850 was very rich on the "Kummelbank" (named after this species). In the Sound and the Beltsea it has been recorded between July and October — a single individual at 40 m. depth in the Sound in January (Biol). The stock seems to have been decreasing since the beginning of this century. From 1880—1904 it has been recorded six times in the southern Kattegat and the Beltsea, but twice only during the following 25 years, in spite of the fact that the fishing intensity has grown considerably in that period — and especially so in deeper water. It is unlikely, that all catches were reported. — The decreasing occurrence may be due to a general decrease in the total stock of the species. Hickling[34]) has shown that the number of large hake has definitely decreased W. of Scotland and in the North Sea; this author also thinks that the hake in the Skagerak and the adjacent part of the North Sea form a separate group — but if so, also this group seems to show declining occurrence of larger specimens like the Atlantic group.

**Autumn and winter.**

The **Conger vulgaris** Cuv. has been recorded in the Transition Area during the following months:

A. C. Johansen has previously drawn attention to this phase-displacement and says that the time that elapses from its general appearance in the Skagerak (August—October) until it appears in the Sound and the Beltsea is somewhat longer than the time it takes the lower current to reach these areas[35]). In accordance with the annual changes discussed in another article in this volume the phase-displacements agree very well with the water transport at this time of the year.

Specimens recorded during the winter have mostly been found washed ashore dead and although in the inner part of the area it is a pronounced autumn-winterguest it cannot survive the cold.

Johansen states that this species arrives with the lower current; and this agrees with the fact that catches by seines most frequently happen at

[33]) D. T. Ahrensberg: Nyt svensk Fiskeri Tidsskrift, 1920, p. 112.

[34]) cp. C. F. Hickling: The Natural History of the Hake. Part III — Ministry of Agric. and Fisheries. Fish. Invest. Ser. II. Vol. XII. No. 1. London. 1930.

[35]) Dansk Fiskeritidende, 1920, p. 74.

ater depths, and when washed ashore dead it is y often after a strong offshore storm that forces bottom water to rise in the lee-side. This was case when an individual drifted ashore on the n of December 1920 in the Kallundborg fjord; preceding wind had been eastern on the 12th 13th it was E. and ESE., force 5—8.

Occurrence in the inner waters is supposed to defined by decreasing salinities (J o h a n s e n *cit.*); but it has twice been recorded on the ish coast of the Baltic[36]).

Secular variations in its appearance are un-ain. Records do not seem to show any marked ency of regular appearance apart from the fact it seems to be less common this century than he last 20 years of the last; in spite of the more nsive fishery almost equal numbers have been rded during the winters of the two periods. As he southern Kattegat, the Belts and the Sound ems to arrive during the secondary maximum alinities in the lower layer (cp. Fig. 3 in tribution I of this vol.), caused by the com-atively strong SE.-winds. It may travel in the rn, deep Kattegat as far as the Sound without g forced into more shallow water or into lower ities than normally exist in its natural areas listribution; in order to reach the Beltsea and Baltic, on the other hand, it has to pass tresh-of smaller depth and normally it encounters hese areas a lower salinity. After 1880, it has e to the latter areas in December 1882 (Kiel)[1]) in January 1889 (Kalundborg Fjord, (FT)) n dominating eastern winds during the 4th ter had caused especially strong inflow, further, pril 1904 (Little Belt, FT) after comparatively ng SSW.-winds during the 1st quarter, and in ary 1920 (Langeland, FT) and December of same year (Kallundborg), during both 4th ters, comparatively slight W.-winds had caused mparatively strong inflow of lower current, in ary 1930 (Little Belt and Samsø, Biol.) — in h case the 4th quarter of 1929 records excep-lly strong SW.-winds had pressed extraordinary rmasses southwards both in upper and lower r.

Finally, when found in Febr., 1936, at Kerte-le (Biol.) the SE.-winds had been much more uent than usual in January as well as the 4th ter of 1935.

The appearance of this species in the southern gat near the entrance to the Sound is ubtedly somewhat influenced by the strength e inflow, but certainly also depending on the erak stock which seems to vary considerably. German fishery, however, being the only one h in this area has taken any interest in this es has been subject to so great variations that ng definite can be said about fluctuations. annual catch from the Skagerak during 1905—13 amounted to 100—2500 kg. only, maxima during these years occurring in 1905—06, 1908 and 1912. During the same period the records from the entrance to the Sound are dated: December 1905 and autumn 1912.

As far as the North Sea is concerned England and Scotland have had specially large yields during 1903—09, in 1914, 1920—23, and in 1927. Its variations agree astonishingly well with variations in salinity in the Channel and the southern North Sea[37]).

## III. Summary.

Characteristic of most of the guests is that they appear several months earlier in the Skagerak and the Kattegat than in the Beltsea, and here, earlier still than in the Baltic. This is the case with *Mugil chelo, Labrax lupus* and *Sarda pelamis* a. o.

Some species, such as *Xiphias gladius, Brama rayi* and *Mola mola,* appear almost simultaneously in all districts. The failing of a phase difference has been explained by the fact that they may arrive into the Skagerak in intermediate layers and therefore are not observed until they stray into regions of lesser depths within the Transition Area.

The disappearance of the Rays' bream and the sunfish happens fairly suddenly by the end of the 4th quarter; undoubtedly when they emigrate or die on account of too low a temperature. As far as the sunfish is concerned there can be no doubt that specimens arriving late in the year become paralysed from cold and drift ashore dead or dying.

Dividing the visitors according to season we find that most "seasons" to some extent show special characteristics:

**1st and 2nd quarter.**

Deep sea (and northern) species from the Skagerak approach coastal waters: during 1st quarter: *Laemargus borealis, Lophius piscatorius* a. o.; 1st and 2nd quarter: *Phycis blennoides* and *Molva byrkelange* a. o. A northern pelagic species, the *Trachypterus arcticus,* left at the mercy of currents, is recorded well into the 3rd quarter.

**2nd quarter.**

Pelagic deep-sea species from the deeper parts of the "Gulf Stream": *Lampris guttatus.*

**2nd and 3rd quarter.**

a. The numerous immigrations of warm water species, that begin about May with *Caranx trachurus* and *Clupea pilchardus* as well as *Rhina squatina,* followed about June by *Sarda pelamis, Sciena*

[1]) Fiskeritidskrift for Finland, 1934, p. 102.

[37]) I. P. J a c o b s e n: Temperature and Salinity at the surface of the North Sea and the English Channel. — Conseil International etc. Special publication. 1934.

*aquila, Polyprion americanum, Engraulis encrasicholus* and *Trygon pastinacea.* About July the *Thunnus thynnus* appears with *Euthynnus pelamis, Orcynopsis unicolor* and *Alopias vulpes* and about August *Zeus faber, Auxis rockei, Xiphias gladius, Lichia glauca* a. o.

b. Southern coastal fish and southern bottom species from minor depths arrive about August/Sept. By August/October we record *Mullus surmuletus, Labrax lupus* and from Sept. onwards the mullet species.

**4th quarter.**

Pelagic ocean species from warmer areas of the Atlantic, *Mola mola,* and *Brama rayi;* these species die as soon as the water is cold and are not recorded in 1st quarter.

**4th and 1st quarter.**

a. Northern bathypelagic species, viz. *Argentina silus* and *Maurolicus mülleri* arrive during the 4th quarter and stay well into the 1st.

b. Southern bottom species: the Conger eel.

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A comparison between the secular variations in the occurrence of species and metcorological-hydrographical conditions points towards the influence of the currents.

The fluctuations in occurrence show characteristic covariation with the fluctuations of the wind (measured by the difference in air-pressure Fanø-Skaw, Copenhagen-Skaw and Fanø-Copenhagen) partially also with the variations of salinity. By a comparison with the salinity it should be remembered that the salinity is determined also by other factors than the strength of the current.

a. Guests, at home in upper water layers of the Atlantic, e. g. the tunny (Fig. 5) show pronounced covariations with the predominance of the western winds. The appearance of such fishes has increased during the last 25 years, especially since about 1920.

b. Guests, at home in deeper water layers and coming to the Transition Area from the northern part of the North Sea, show a more or less pronounced tendency to the opposite variation. This is the case with the Mackerel in the Skagerak.

c. A guest from intermediate layers north of the North Sea, e. g. the kingfish coming from the deeper layers of the "Gulfstream", shows a distinct inverted covariation with the dominance of western and southwestern winds.

The changes in these winds have produced an increased inflow to the northern North Sea from intermediate water layers of the Norwegian Sea (including the nether layers of the "Gulfstream") during the years 1880—1905 and since about 1930 (cp. Fig. 3).

d. Fishes from the intermediate or lower layers of Skagerak (most of the winter guests, the *Zeus faber* a. o.) seem to follow the same rule. Also the north-southern component of the wind influences the inflow through the Kattegat in such a way that northern winds diminish the inflow, southern winds intensify it.

e. Coastal fishes from the southern North Sea and adjacent parts of the Atlantic (anchovy, sardine, bass and red mullet) show a weak tendency to covariation with the degree of predominance of western and south-western winds.

Since about 1920 the increase of the western winds has augmented the number of guests from the eastern Atlantic off the Spanish and Portuguese coasts.

Since 1928 the strong south-western winds have caused a strengthening of the inflow to the North Sea from the nether layers of the "Gulfstream" and other intermediate layers in the Norwegian Sea. This has been noticeable in the Skagerak also.

Therefore, during this last period — especially since 1930 — the Transition Area has been visited by species also from more distant parts of the North Atlantic "Gulfstream" area and from deeper parts of the "Gulfstream".

Until 1928 similar winds caused a decreasing inflow in the lower layer through the Kattegat, since then an increased inflow, strongly augmenting the number of guests in the Beltsea.

The strengthening of the inflow has been specially marked on the fauna of Bohuslän*), but also at the Skaw**). The appearance of some southern *Scyphomedusæ* has been discussed by L. P. Kramp†).

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*) cp. e.g. Einar Lönnberg och Gunnar Gustafson: Från Kristinebergs zoologiska Station sommaren 1935. — Fauna och Flora. 1935, p. 241.

**) Ellen Thomsen: *Sepia officinalis* L. found alive in Danish waters. — Vid. Medd. dansk naturh. Foren. Bd. 97, 1933.

†) L. P. Kramp: An exceptional occurrence of *Rhizostoma octopus* and *Chrysaora hysoscella* in the Danish waters in 1933. Journal du Conseil, Vol. IX. p. 211.

# APPENDIX

# THE COMPOSITION OF THE POLISH SPRAT CATCHES IN THE BAY OF DANZIG IN THE SEASONS 1934–'35 AND 1935–'36.

BY

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(MS. received June 1936)

keeping with the research programme established by the International Council for he Exploration of the Sea, we have continued work on the analysis of the Polish sprat catches, menced in the season 1931—'32, and published Journal du Conseil", Vol. VII, 3, in 1932. The ent treatise is the result of our analysis of the position of the catches in the seasons 1934—'35 1935—'36.

Since the introduction of sprat trawls in lieu ill-nets, the Bay of Danzig has gained increasing ortance in the fishing of the central Baltic.

The annual increase in the number of larger -sea cutters equipped with more powerful rs, the introduction of 120 foot trawls instead 0 foot, trawling with two cutters, etc., have ed a remarkable development of the Polish t fishery, thrusting Poland into a leading place ng the sprat-fishing States of the Baltic.

One might suppose that during the last ten s there should have been certain changes in the ical and biological conditions of the life of the , which would cause fluctuations in the catches rding to the fertility or sterility of one or er age-group.

uch fluctuations in the catches are common to arieties of edible fish, even to a fish so closely ed to the sprat as the herring. However, the catches in the Bay of Danzig, in which nd, Germany and Danzig participate, show er fluctuation nor stabilisation during the last years. On the contrary, there is a constant ase in the catches, as may be seen from the h of Polish catches for the last fifteen years. comparatively small space within which the shoals of the Bay of Danzig are confined. her with the increasing number of cutters and s, probably discount the fluctuations, so that changes which may take place in the life of hoal are as yet undefineable by us.

he period from 1921 to 1929 is a period of es by means of passive gears, that is to say, ill-nets, and is marked by fluctuation of the es, falling in 1926 to 182 tons. Since 1930

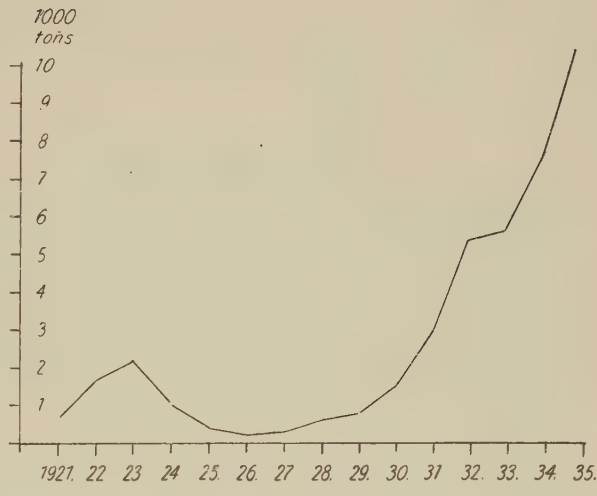


Fig. 1.

active gears, trawls, have been used, and the curve has mounted steadily without break, in 1935 reaching the record figure of 10,500 tons. Of the total of 42,112,669 kg. caught during this period, some 34,000 tons fall to the six years during which trawls were used and only some 8,000 tons to the nine years of gill-net fishing.

The raw material of the sprat trade is composed of sexually mature sprats at the time of their spawning migrations in large shoals to the shores of the Bay of Danzig. The first, inconsiderable shoals, coming from the north, appear along the coast of the peninsula of Hel, between Rozewie and Jastarnia, in August. During September and October the number of sprats increases slightly, still keeping to the shores of the peninsula, mostly on the side of the Baltic, but partly on the side of the Bay also. These months, however, are not of great importance to the sprat fishing season. Only after October do the real catches begin. The table and curve given below contain monthly data of the catches for the fifteen-year period, 1921 to 1935.

| Month | 1921—1935 kilogr. | % |
|---|---|---|
| I | 8,939,583 | 21.5 |
| II | 9,361,975 | 22 |
| III | 8,672,180 | 20.5 |
| IV | 1,872,980 | 4.5 |
| V | 270,173 | 0.5 |
| VI | — | |
| VII | — | |
| VIII | 11,500 | |
| IX | 10,325 | |
| X | 1,127,935 | 3 |
| XI | 4,657,438 | 11 |
| XII | 7,188,580 | 17 |
| | 42,112,669 | 100 |

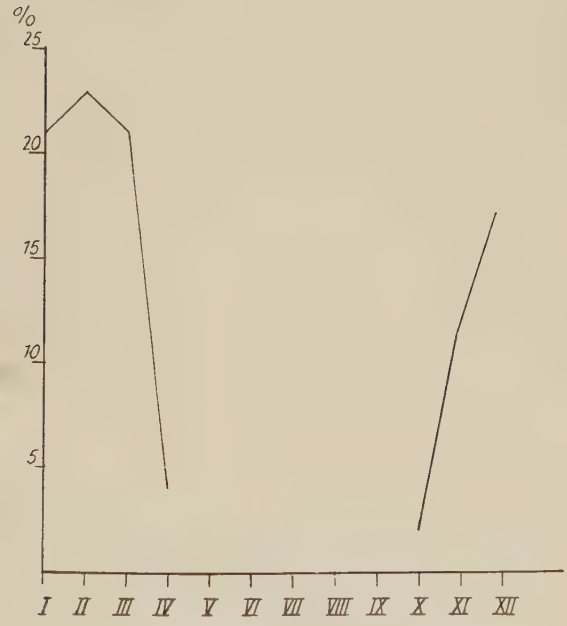


Fig. 2.

The fishing season, then, lasts six months, from November to April, inclusive. It would appear that the comparatively small catches of April are due to the emigration of the sprats returning to the open sea, and to a decline in trawling occasioned by a decline in the market demand, warm weather, and other economic factors. The largest catches, amounting to 22 % of the total annual catches, occur in February. In May the sprat shoals commence their emigration, and the catches fall to 0.5 % of the year's total.

The monthly variations in the sprat catches seem to be closely connected with the thermic factor. Sprat shoals as a rule occupy the warmer levels of water, which accounts for their horizontal migrations between surface and bottom. The data worked out by Mr. Cieglewicz from our questionnaire to the fishermen in the season 1934—'35, and comparison of the size of the catches with the thermic data obtained from our station near Hel for the water appears as follows:

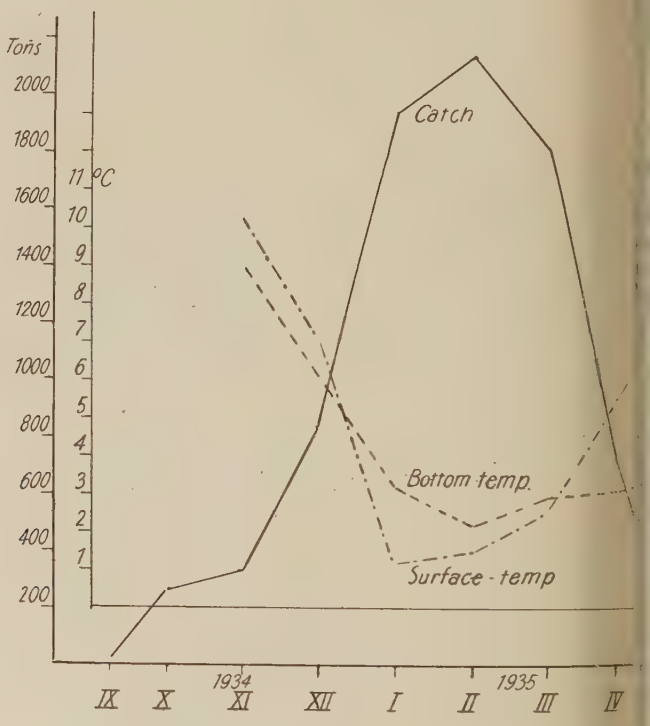


Fig. 3.

The curve shows a considerable increase of the catches during the months of January and February. During these months, on account of the cooling of the upper water level, the temperature of the surface of the sea is lower than that of the bottom. This causes the sprat shoals to congregate in the warmer bottom water and facilitates fishing with a bottom instrument like the trawl. During the months when the surface of the sea has a higher temperature, the sprat shoals rise into the warmer upper water and are more scattered. These conditions impair the efficiency of the trawl and the catches therefore decrease.

**Measurements of the Sprats.** The material used for analysis of the over all body length for the two seasons 1934—'35 and 1935—'36 consisted of 52,699 specimens. The number of specimens analysed at the various dates is given below:

| Season 1934—1935. Date | Number of fishes | Season 1935—1936. Date | Number of fishes |
|---|---|---|---|
| XI.34 | 685 | 9.XI.35 | 4420 |
| XII.34. | 736 | 26.XI.35 | 4253 |
| XII.34 | 853 | 22.XII.35 | 5337 |
| XII.34 | 613 | 2.I.36 | 5156 |
| I.35 | 1638 | 28.I.36 | 4244 |
| I.35 | 1088 | 10.II.36 | 5009 |
| II.35 | 3067 | | |
| II.35 | 4783 | | |
| II.35 | 5782 | | |
| III.35 | 5035 | | |
| | 24280 | | 28419 |

The size of the sprat caught in the Bay of nzig varies from 6.5 to 15 cm. In grouping the according to over all body length, we have ided them into 18 half-centimetre groups. The owing table gives the results of these measure- nts and also the percentages of the different -groups in the sprat shoal.

| gth | Season 1934—35 No. of ind. | % | Season 1935—36 No. of ind. | % |
|---|---|---|---|---|
| 5 | 2 | — | 20 | — |
| 0 | 11 | — | 22 | — |
| 5 | 20 | — | 65 | — |
| 0 | 222 | 1 | 263 | 1 |
| 5 | 693 | 3 | 484 | 2 |
| 0 | 503 | 3 | 336 | 1 |
| 5 | 144 | 0.5 | 139 | 0.5 |
| 0 | 123 | 0.5 | 302 | 1 |
| 5 | 308 | 1 | 2104 | 7 |
| 0 | 1959 | 8 | 4049 | 14 |
| 5 | 4903 | 20 | 5456 | 20 |
| 0 | 7706 | 32 | 6525 | 23 |
| 5 | 4538 | 19 | 5172 | 18 |
| 0 | 2212 | 9 | 2678 | 10 |
| 5 | 880 | 3 | 655 | 2 |
| 0 | 53 | — | 140 | 0.5 |
| 5 | 3 | — | 8 | — |
| 0 | 1 | — | 1 | — |
| | 24,281 | 100 | 28,419 | 100 |

As appears from the above table, the largest rcentage in both seasons is occupied by the cm. fish. The shoals are composed mainly of e sprats of 11 to 15 cm. These length-groups ount for 91 % in the season '34—'35 and 5 % in the season '35—'36. As the various can- industries use fish of 10.0 cm. and upwards, as of importance that the admixture of small, ess sprats did not exceed 7.5 % in the season —'35 and 5.5 % in the season '35—'36. In this ulation we omit the extreme groups of 6.5 to cm., as their proportion to the whole would to be expressed in hundredth-parts of per .

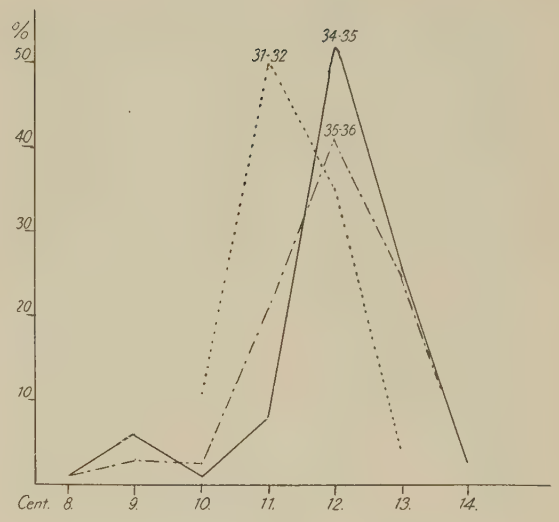

Fig. 4.

In order to compare the composition of the shoals with that in our former analysis (for the season 1931—'32) and to trace any changes that may have arisen, we give below a graph composed of three curves. In the season 1931—'32 the largest percentage was of 11 cm. specimens; in the last two seasons, however, the curve has shifted to the right, and the material supplied for the fish industry is mainly (83 % and 75 %) composed of sprats of more than 11 cm. We shall revert to these curves in dealing with the composition of the shoal with regard to age. We may suppose, however, that the enormous increase of sprat trawling, which we see in the last few years, may have had some effect in thinning out the stock. This thinning out has, as is usually the case, involved a diminution of competition and improvement of growth conditions. The curves for the last two seasons show no changes and are completely parallel, which seems to point towards a certain stabilisation of the sprat fishery in the Bay of Danzig. An analysis of weight bears out this supposition.

**Weight of the sprats.** In order to establish the weight of the various length groups and the average weight, we adopted the following method. While analysing individual specimens from each catch, ten fish were weighed from each group and the average weight for the group estimated. The total of these average weights of all the specimens analysed, divided by their number, gave us the average weight for each length-group. By means of this we estimated the weight of all 52,699 specimens analysed by us, obtaining in this way the following tables:

Season 1934—35.

| Length cm. | No. of ind. P. | Average weight gr. W. | Total aver. |
|---|---|---|---|
| 6.5 | 2 | 1.2 | 2.4 |
| 7.0 | 11 | 1.7 | 18.7 |
| 7.5 | 20 | 1.8 | 36.0 |
| 8.0 | 222 | 3.1 | 688.2 |
| 8.5 | 693 | 3.3 | 2286.9 |
| 9.0 | 503 | 3.9 | 1961.7 |
| 9.5 | 144 | 4.5 | 648.0 |
| 10.0 | 123 | 5.6 | 688.8 |
| 10.5 | 308 | 7.5 | 2310.0 |
| 11.0 | 1959 | 8.8 | 17239.2 |
| 11.5 | 4903 | 9.8 | 48049.4 |
| 12.0 | 7706 | 11.0 | 84766.0 |
| 12.5 | 4538 | 12.0 | 54456.0 |
| 13.0 | 2212 | 13.1 | 28977.2 |
| 13.5 | 880 | 14.0 | 12320.0 |
| 14.0 | 53 | 14.8 | 784.4 |
| 14.5 | 3 | 15.1 | 45.3 |
| 15.0 | 1 | 19.0 | 19.0 |

$\Sigma = 255{,}297.2$ gr.

$$\text{M/average weight} = \frac{\Sigma PW}{n} = \frac{255{,}297.2}{24{,}281} = 10.5 \text{ gr.}$$

Season 1935—36.

| Length cm. | No. of ind. P. | Average weight W. | Total aver. |
|---|---|---|---|
| 6.5 | 20 | 1.6 | 32.0 |
| 7.0 | 22 | 2.0 | 44.0 |
| 7.5 | 65 | 2.1 | 136.5 |
| 8.0 | 263 | 2.5 | 675.5 |
| 8.5 | 484 | 3.4 | 1645.6 |
| 9.0 | 336 | 3.5 | 1176.0 |
| 9.5 | 139 | 4.7 | 653.3 |
| 10.0 | 302 | 6.3 | 1902.6 |
| 10.5 | 2104 | 6.9 | 14517.6 |
| 11.0 | 4049 | 8.0 | 32392.0 |
| 11.5 | 5456 | 8.6 | 46921.6 |
| 12.0 | 6525 | 10.4 | 67860.0 |
| 12.5 | 5172 | 11.5 | 59478.0 |
| 13.0 | 2678 | 12.8 | 34278.4 |
| 13.5 | 655 | 13.0 | 8515.0 |
| 14.0 | 140 | 15.0 | 2100.0 |
| 14.5 | 8 | 15.0 | 90.0 |
| 15.0 | 1 | 17.0 | 17.0 |

$\Sigma = 272{,}435.1$ gr.

$$\text{M/average weight} = \frac{\Sigma PW}{n} = \frac{272{,}435.1}{28{,}419} = 9.5 \text{ gr.}$$

The average weight of a sprat given by us in our former treatise, for 1931—'32, was 8.0 gr. It follows that the weights of the various length groups in the season 1934—'35 had increased by 2.5 gr. from those of 1931—'32, and those of the present season by 1.6 gr.

Bearing in mind the well-known fact (S u n d, H e s s l e) that the sexually mature sprat feeds sparsely or not at all during the autumn and winter period, but lives on the fat accumulated in the summer, we expected to find considerable differences of weight at the beginning and at the end of the season. This proved to be the case: but the difference in average weight of the sprats in the various length groups proved to be less than anticipated. We give below a comparison of the average weights in December and March:

| Length cm. | December 1934 aver. weight gr. | March 1935 aver. weight gr. | Difference of the weight. gr. |
|---|---|---|---|
| 7 | 2 | — | — |
| 7.5 | 2.3 | — | — |
| 8 | 3.1 | 2.6 | 0.5 |
| 8.5 | 3.8 | 3.0 | 0.8 |
| 9 | 4.3 | 3.3 | 1.0 |
| 9.5 | 5 | 3.8 | 1.2 |
| 10 | 7 | 3.9 | 3.1 |
| 10.5 | 8 | 7.3 | 0.7 |
| 11 | 9.2 | 8.6 | 0.6 |
| 11.5 | 10.3 | 9.4 | 0.9 |
| 12 | 11.3 | 10.3 | 1.0 |
| 12.5 | 12.8 | 11.9 | 0.9 |
| 13 | 13.7 | 12.8 | 0.9 |
| 13.5 | 14.8 | 13.6 | 1.2 |
| 14 | 16 | 14.3 | 1.7 |

During this period, then, the decline in the weight of the sprat varies from 0.5 to 1.7 gr. A certain number of sprats remain in the Bay of Danzig during the summer, and in 1935 we made three analyses of weight in June, one in July and one in August. These analyses gave us the following decline in weight, as compared with the weight in November:

1934—1935

| Length cm. | 11 | 11.5 | 12 | 12.5 | 13 |
|---|---|---|---|---|---|
| Weight gr. | | | | | |
| November | 9.3 | 10.3 | 11.5 | 13.0 | 13.4 |
| June | 9.1 | 10.1 | 11.2 | 12 | 12.6 |
| Difference | —0.2 | —0.2 | —0.3 | —1.0 | —0.8 |

| Length cm. | 11 | 12 | 12.5 | 13 |
|---|---|---|---|---|
| Weight gr. | | | | |
| November | 9.3 | 11.5 | 13.0 | 13.4 |
| July | 9 | 11.2 | 12 | 13.6 |
| Difference | —0.3 | —0.3 | —1.0 | +0.2 |

| Length cm. | 11 | 12 | 13 |
|---|---|---|---|
| Weight gr. | | | |
| November | 9.3 | 11.5 | 13.4 |
| August | 8.8 | 10.2 | 10. |
| Difference | —0.5 | —1.3 | —3.( |

It appears, then, that the average March weigh is lower than the average November weight. I June and July the diminution is less than in March

bite the fact that 16 to 42 % of our specimens ripe roes. This is due to the fact that in June July, at spawning time, the sprat begins to feed makes up to some extent the loss of weight of gonads. The August material contained speci- s which had already spawned, and as feeding ld not make up for the loss of weight of the le gonads, the decline in weight is increased. August is probably the transition month in this ect, as after spawning begins the period of nsive feeding during which are amassed the plies of fat to be seen on the sprat in No- ber.

On the basis of eight analyses (after unpublished of Sterlingov) chemical composition of whole sprat during the period from December ne, by Saxlet's method, we have obtained following curves, giving the percentages of r and fat.

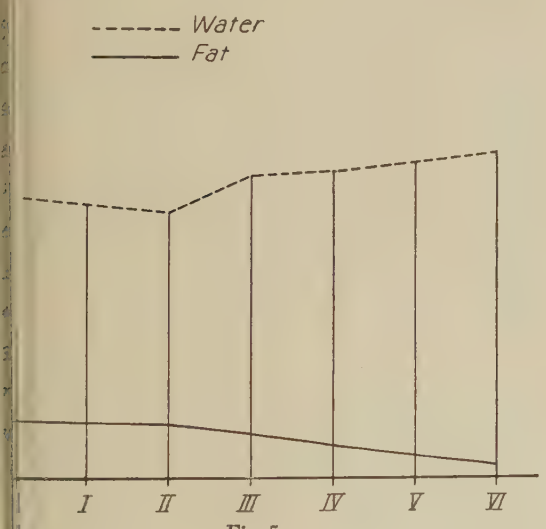


Fig. 5.

he data of these analyses show that the amount ater varies from 63.5 to 80.5 %, and the nt of fat from 14.2 to 3.57 %. From ary onwards we observe a steady increase in ercentage of water, which, by June, amounts .5, i. e., 15 % more than in February. This se in the amount of water is accompanied decrease in the amount of fat, which in June, is at spawning time, falls to 3.57 % (the f weight of the body being 10.1 %). That is that water makes up for the weight lost on nd this accounts for the evenness of weight we observed in our investigations of the in the Bay of Danzig.

ur data for the amount of fat differ from of Sund for the Norwegian sprat. Accord- Sund's data, the increase in the amount of parallel to the increase of the temperature of the water, so that the maximum percentage of fat ($> 14$) occurs in the different years in September, when the temperature of the water is $> 12°$. In our material, the maximum percentage of fat (14.2) was found in 1934 to occur in December, with an average temperature of the water of 4.94°, and the minimum percentage (3.57) in June 1935, with the water at a temperature of 14°. English investigators also state that in the English catches of 1932—'33 the maximum percentage of fat occurred in December, just before the New Year. (Report on Sea Fisheries. 1932).

This difference arises from the fact that the Norwegian sprat fishery is quite different not only from that of the Baltic, but also of the North Sea. The sprat fishing season of England, Scotland, Belgium and Germany is from December to March, and the fishery is based, like the Polish, on the catching of mature and older fish (from three to five years of age), when they come to the shores in large shoals before spawning. The sprat fishing on the Norwegian fiords, on the other hand, subsists exclusively on the young, sexually immature 1½ to 2 year old sprats coming up the fiords for feeding. Indeed, according to Hjort, the high value of this type of sprat is due to their youth. The fishing season, as established annually by the owners of the fish canning factories, lasts from the end of May or early June to the middle of November or even to January (Hjort). It appears, then, that Sund's data as to the amount of fat has regard to young, immature fish at the time of their feeding, and so is naturally connected with the thermic factor. In technical literature about the sprat, one often sees the "fat" Norwegian sprat compared with the "thin" sprat of other parts of the North Sea. This is due to the fact that the spawning period is very extensive in the North Sea, lasting from January to August. During the fishing season, therefore, some of the fish are caught just before spawning when the amount of fat is very small. In this respect conditions are better in the Baltic. The spawning period is less extensive, lasting through June and July (Hessle, Schneider, Ehrenbaum), when the sprats have already migrated to the open sea. In any case, the Polish fish canning industry handles quite high value material throughout November, December, January and February (from 14.2 to 13.3 % fat), and only in March (11.1 %), and especially in April (8.3 %) the material is inferior.

In a paper read at the International Council for the Exploration of the Sea in 1930 about unifying the methods of investigation of the fluctuations in the composition of sprat stocks, the Norwegian investigator, Bjerkan, recommended the employment of his modification of Fulton's formula. This formula is intended to serve for defining the indicator of the quality of the sprat. This formula ($i = 1000\ p : l^3$) differs from that of Fulton in

that the weight is multiplied by 1,000 and not by 100. Unfortunately this formula can be applied only to feeding fish and not to sprats in the pre-spawning shoal in the autumn and winter. The basic factor of this formula is weight, and with our material the changes in weight during the fishing season are insignificant, and if we used this formula during the fishing season and even during spawning we should have an almost unchanged indicator.

According to Bjerkan, the size of this factor is as follows:

spring — 7
summer — > 8
autumn — from 0.5 to 8.

According to this, our December sprat with 14.2 % fat ought more or less to correspond with the Norwegian summer sprat with a coefficient of > 8. Let us now compare our high value Derenders it impossible to apply Bjerkan's with the sprat with 3.57 % fat caught during spawning in June and July.

| Length | Indicator | | |
|---|---|---|---|
| | XII | VI | VII |
| 11 | 6.8 | 6.7 | 6.7 |
| 12 | 6.6 | 6.4 | 6.4 |
| 13 | 6.2 | 5.7 | 6.1 |

The coefficient obtained by us for December does not correspond in value to that of Bjerkan. The reason for this is that, according to Sund's three year analyses, the sprat of the Norwegian fiords contains from 11.25 to 15.5 % fat (June to December 1908), while the percentage of fat in our sprats during the same period varies from 3.57 to 14.2. But an almost equal coefficient of quality for the periods of maximum and minimum fat, caused by the small difference in weight of the sprat, renders it impossible to apply Bjerkan's formula to the sprats of the Bay of Danzig.

**Losses of the sprat stock.** Our calculations of the average weight of sprats allow us to estimate roughly the losses inflicted on the sprat stock of the Central Baltic by Polish trawls during the last two years, 1934 and '35.

| Year | Av. weight gr. | Total catch kg. | No. of ind. | No. of ind. in millions |
|---|---|---|---|---|
| 1934/35 | 10.5 | 7,448,050 | 709,338,095 | 709 |
| 1935/36 | 9.6 | 10,407,740 | 1,084,139,583 | 1084 |
| Total | — | 17,855,790 | 1,793,477,678 | 1793 |

That is to say that Polish fishermen have caught nearly two milliard sprats during the last two years. In the season 1934—'35, 7.5 % of this number, and in 1935—'36, 5.5 % were too small to be of use to the manufacturers. There were, then 113 mill. of small sprats.

**Age.** In grouping the fish according to age, we adopted Morozow's method as applied by him to the *Rutilus rutilus* in Turkmania. On the basis of 1562 otoliths from the December sprat catches of 1935, we drew up the following table of age-groups and of the proportional percentage of these groups to each length group.

| Length cm. | Age-groups % 1929 VI summer belts | 1930 V summer belts | 1931 IV summer belts | 1932 III summer belts | 1933 II summer belts | No. of ind. |
|---|---|---|---|---|---|---|
| 6.5 | — | — | — | — | 100 | 15 |
| 7 | — | — | — | — | 100 | 38 |
| 7.5 | — | — | — | — | 100 | 35 |
| 8 | — | — | — | — | 100 | 80 |
| 8.5 | — | — | — | — | 100 | 80 |
| 9 | — | — | — | — | 100 | 70 |
| 9.5 | — | — | — | 9 | 91 | 44 |
| 10 | — | — | — | 100 | — | 129 |
| 10.5 | — | — | — | 100 | — | 120 |
| 11 | — | — | 3 | 97 | — | 164 |
| 11.5 | — | 2 | 58 | 40 | — | 157 |
| 12 | — | 7 | 83 | 10 | — | 194 |
| 12.5 | — | 9 | 88 | 3 | — | 165 |
| 13 | — | 22 | 73 | 5 | — | 168 |
| 13.5 | — | 73 | 27 | — | — | 68 |
| 14 | 10 | 46 | 44 | — | — | 30 |
| 14.5 | 10 | 46 | 44 | — | — | 10 |
| | | | | | | 1562 |

Using this table, we divided all our material that is 28,419 specimens, into age-groups on the following principles: we included all fish of 6 to 9 cm. length in the 1933 year-class, fish of 9.5 cm. we divided between the 1933 and '32-classes in the proportion of 91 to 9, fish of 11.5 cm. we divided between three classes in the proportion of 2, 58, 40 and so on.

A table of our measurement material drawn up in this manner gave us the following features of the composition of the stock with regard to age and growth.

(See next page).

The pre-spawning shoal of sprats in December 1935 consisted of 4 age-groups, that is, of 2+, 3+, 4+, and 5+. The plus after each group is due to the fact that we take the birth month of sprats to be June or July, but the otoliths were taken in December. Three or four months had, therefore, elapsed between the last summer period, 1935, and the moment of acquiring the winter ring of 1936.

Four-year fish are in majority, amounting to 54 %; next come three-yearlings with 34 %, in the third place five-yearlings with 8 %, and in the fourth place two-yearlings with 4 %. Of the 52,69

| ps | Length cm. 6.5 | 7 | 7.5 | 8 | 8.5 | 9 | 9.5 | 10 | 10.5 | 11 | 11.5 | 12 | 12.5 | 13 | 13.5 | 14 | 14.5 | n | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ner | 20 | 22 | 65 | 263 | 484 | 336 | 127 | — | — | — | — | — | — | — | — | — | — | 1317 | 4.6 |
| ner | — | — | — | — | — | — | 12 | 302 | 2104 | 3928 | 2182 | 653 | 155 | 133 | — | — | — | 9469 | 33.3 |
| ner | — | — | — | — | — | — | — | — | — | 121 | 3165 | 5415 | 4551 | 1956 | 177 | 55 | 1 | 15441 | 54.4 |
| ner | — | — | — | — | — | — | — | — | — | — | 109 | 457 | 466 | 589 | 478 | 64 | 4 | 2167 | 7.6 |
| ner | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 21 | 3 | 24 | .1 |
| | 20 | 22 | 65 | 263 | 484 | 336 | 139 | 302 | 2104 | 4049 | 5456 | 6525 | 5172 | 2678 | 655 | 140 | 8 | 28418 | 100 |

cimens examined, there were only 24 specimens, t is but 0.04 % of six-year old specimens, that f fish which are probably in their last year of

Analysing mathematically the columns for the ious age-groups, we get the following average y-lengths for each year-group:

| Age | M Aver. Length cm. | ± σ | ± m |
|---|---|---|---|
| 2+ | 8.5 | 0.543 | 0.015 |
| 3+ | 10.8 | 0.611 | 0.006 |
| 4+ | 12.1 | 0.658 | 0.005 |
| 5+ | 12.7 | 0.636 | 0.013 |

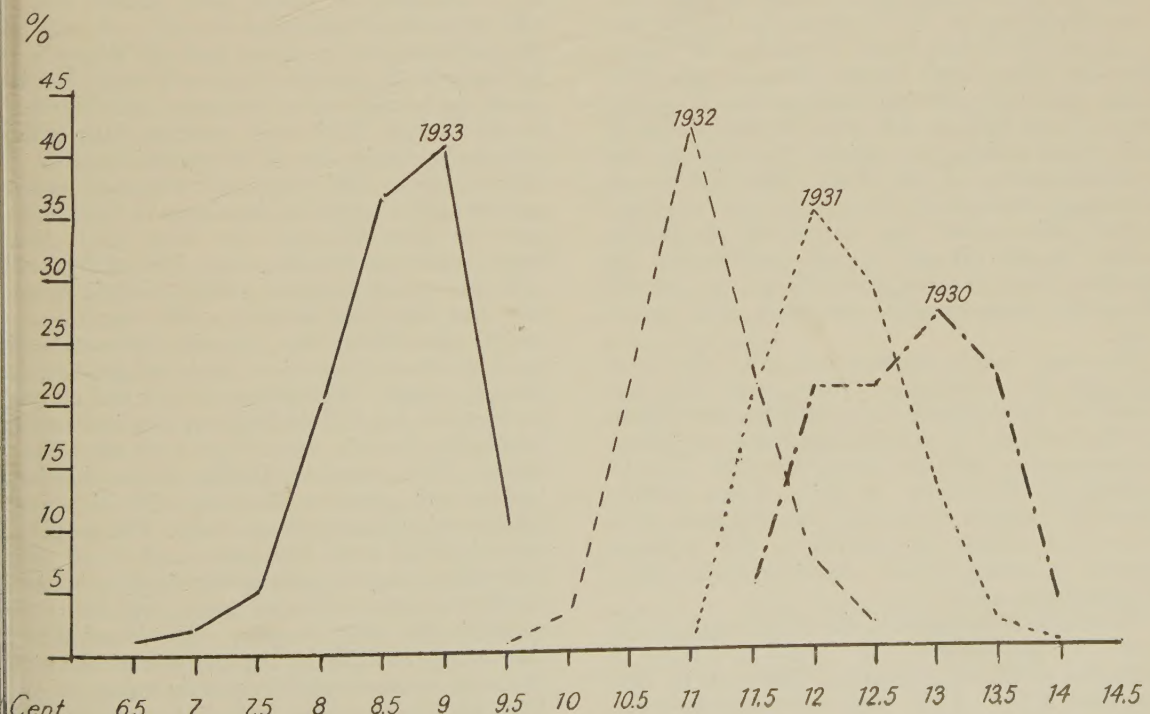


Fig. 6.

The fairly long period of spawning, probably extending over more than two months, causes considerable variation in the lengths of the various year-groups, as will appear from the above curves plotted for the four age-groups occurring in the catch of the season 1935—36.

The body-length of each year-class varies to the extent of 4 cm., and the limits of these variations are as follows:

| | | | | |
|---|---|---|---|---|
| two-early | from | 6.5 | to 9.5 | cm. |
| three-yearly | „ | 9.5 | „ 12.5 | „ |
| four-yearly | „ | 11 | „ 14 | „ |
| five-yearly | „ | 11.5 | „ 14.5 | „ |

Only the year-group of 1933 has different variation limits and a different peak to the curve; the other curves are typically intersecting.

On account of the well known technical difficulties in the way of mass determination of the age of sprats by means of their scales, Bjerkan suggests in the above-mentioned paper that estimation on the basis of the scales can serve only as an auxiliary check. Investigations for establishing age should be based on length measurements, which, according to Bjerkan, in all cases correspond to the composition of the catch. (Rapports et Procès-Verbaux. Vol. LXVIII, 1930.) We fear that with pre-spawning shoals of sprats, containing various year-groups, the general use of measurement without a considerable number of direct age definitions might be misleading.

For instance, in this paper we are dealing with the measurements of 52,629 specimens for the two seasons and 1569 definitions of age for the season 1935—'36. The length curves, with the exception of that for 1933, are intersecting, that is to say that one year follows the next, so that fishes of equal length belong to various year-groups. In our length curve for fish of the 1935—'36 season we have only two peaks of the curve for four year-groups. This means that unless we obtain the average length of the various year-groups by numerous direct investigations of age, we cannot deduce the composition of the stock with regard to age.

Wholesale length measurement may give good results for the two youngest year-groups (1½ and 2 years) of fiord sprats, with which the Norwegian sprat trade deals, but working under our conditions, it is essential to rely on numerous direct age determinations. Moreover, as Hjort has already proved with regard to herrings, the old method of Petersen cannot be applied to fish with an extensive spawning period (especially older fish), and sprats are such.

Especially remarkable in the body-length curves for the last two seasons is the small percentage of fish of 6.5 to 9.5 cm., that is of fish born in 1933 (less than 4 %). This does not mean, however, that the supply of this year-group is exhausted, as in the 1935—'36 season three-year-old fish accounted for 34 %, and the fish of this year-group occupied the second place. The small percentage of two-year-old fish may be explained by the supposition that only a small number of earlier mature two-year-olds take part in the autumn-winter pre-spawning migration, whereas the remainder of this year-group stays as immature in the open sea. Belly sections of the fish of 6.5 to 9.5 cm. show that their gonads are in the same stage of development as those of the older fish.

**Rate of growth.** In dealing with the rate of growth of Middle Baltic sprats, the first consideration is the method to be employed in estimating age. In the literature devoted to this subject (Sund, Ehrenbaum, Schneider, Jenkins, Hidrich, Bjerkan) there is no detailed explanation of the scale and otolith as means of calculating age. The basic fact for establishing age and rate of growth is the time of acquiring the first winter ring on the scale or otolith, and this is passed over in the above mentioned literature. But only by establishing the time of acquisition of this ring can we proceed to the wholesale determination of age, for instance by otoliths, on which this ring is generally merged into the second summer belt. As is well known, the spawning period of sprats in the North Sea is exceptionally extensive. The spawning begins earliest in the south-west, near to Plymouth, where its period is from January to April (Ehrenbaum) and even, according to newer data, extends into July (Hefford). According to Bjerkan's data, the period for the northern part of this sea is from February to September. In the Western Baltic the spawning period is in February and March, and in the Eastern Baltic still later, in June and July and probably in the first part of August. It is obvious, then, that with such extensive spawning period sprats born, for instance, in February will grow to quite different size from sprats born in July, August or October. The former, by analogy with the spring herrings, will have their first summer belt of quite normal width, the latter very broad, since with them, as with autumn herrings, the first winter ring arises on the scales only in the second winter. According to Hessle, autumn herrings of the Middle Baltic spawn in August and September, that is more than a month later than sprats. The scale of Middle Baltic herrings is typical and possesses the very wide first summer belt peculiar to the autumn race. The scale of our sprat has the same character, and if we take the first winter ring of autumn herrings to be the ring of the second winter we must treat the scale of sprats in the same manner. We found this principle borne out also by the analysis of our material obtained in the coastal waters by means of a small Petersen trawl. At the end of August (the 23rd.), and even in September (the 23rd.) we obtained

th this trawl a large number of small post-larval rats in an intermediate stage towards their final rm. The young sprats already possessed all their s, but they were still lengthened in form and the dominal fin was still thrust forward in relation the dorsal fin. The total body-length of the jority of these small fish varied between 30 mm. d 35 mm., but there were some, still younger, 20—25 mm. These young sprats did not yet ssess scales, and the division of the body muscles o miomers so characteristic of fish of the herring mily in their larval and post-larval stages was te distinct. The otoliths of these young sprats l, apart from a transparent nucleus, a very row belt of summer growth. It is beyond doubt t in the calendar year of their birth these young ats, just like autumn herrings, will not yet have omplete and finished scale design with a broad mmer belt and winter ring. There is, indeed, no e for this wide growth belt to be acquired as m September to winter they have barely two nths. Estimating the growth backwards on the is of otoliths and scales, we receive the follow- average lengths of sprats, corresponding to the adth of the primal increase of the scale (from centre to the first distinct winter ring).

| | | |
|---|---|---|
| Length 7 — 7.5 cm. | $l_1 = 5$ | cm. |
| 8 — 8.5 „ | $l_1 = 6$ | „ |
| 9 — 9.5 „ | $l_1 = 6$ | „ |
| 10 — 10.5 „ | $l_1 = 7.7$ | „ |
| 11 — 11.5 „ | $l_1 = 7.8$ | „ |
| 12 — 12.5 „ | $l_1 = 8$ | „ |

If, then, we were to consider this clear winter g, whether on the scale or the otolith, as uired in the year of birth, say in December, growth of our sprats of intermediate form from tember to December, that is in the course of ut three months and at a period of partial riction of growth of organic life at sea, would from 2 to 5 centimetres, which is highly im- bable.

We consider, then, that the first broad growth on the scales of the sprat signifies two summer ods, and not the summer of the birth year. If take the birth months of the Middle Baltic ts as being June and July the first winter ring signify 18 or 19 months. The winter ring of first winter is not visible on the otoliths of ts of from 6.5 cm. On the December otoliths uch sprats we see, besides the centre, a broad mer belt with a transparent edge, i. e. the winter . The otolith gives the impression of a fish has had one summer of life, while at the ent of catching it was living through a winter od. In reality there is in the broad summer belt ery narrow winter ring of the first winter, h has merged into the ring of the second sum- and become invisible. This statement can best ested with sprats of a year and a half and th of 35 to 45 mm. After a storm we found 60 of these in a pool left on the shore of the Baltic on August 31st 1934. These fish probably belonged to the 1933 year-class and came from the last spawning of that year. On the otoliths of these small sprats we distinctly noticed the centre, a very narrow belt of the summer of 1933, representing the very small growth of the year of birth, the first winter ring of 1933—'34 and the summer belt of 1934. The invisible ring of the first winter, which usually merges into the belt of the second summer, can sometimes be revealed by filing the otolith.

In interpreting the otolith then (as well as the scales) we take the first broad summer belt and the first winter ring to signify 18 to 19 months of life. Estimating backwards the growth of the first year, we find the growth of 45 mm., one and a half year sprats to be as follows:

$l_1 = 3.5 — 2.4 — 2.6 — 3 — 3 — 2.8$
$M = 2.8$ mm.

This growth corresponds to the length of the post-larval, transitional sprats of 30—35 mm. caught at the end of August, which we mentioned above.

On the basis of the average body-lengths of the various year-groups, as given by us above, the average growth increments of our sprats appear as follows:

| | | |
|---|---|---|
| 1st summer (year of birth) | 5 | cm. |
| 2nd „ | 3.5 | „ |
| 3rd „ | 2.3 | „ |
| 4th „ | 1.3 | „ |
| 5th „ | 0.6 | „ |

As far back as 1919, Ehrenbaum, comparing the sprats of the Western and Eastern Baltic, declared that the East Baltic sprat is smaller and less well-fed owing to the smaller amount of salt in the water and the poorer conditions of feeding. This statement is borne out by comparison of our material with the data of Sund for Norway and Ehrenbaum for the districts of Eckernförde, Sonderburg and Laboe in the Western Baltic. A comparison of these data is given in the two following tables.

| Age | North Sea by Sund | Bay of Danzig | Difference |
|---|---|---|---|
| | Length cm. | | cm. |
| 1 | 5 — 7.0 | 5 | —2 |
| 2 | 8.5—11.5 | 6.5— 9.5 | —2 |
| 3 | 11 —14 | 9.5—12.5 | —1.5 |
| 4 | 14 | 11 —14 | — |
| 5 | 14.5—15.5 | 11.5—14.5 | —1.0 |

| Age | Aver. length cm. | | | | Difference |
|---|---|---|---|---|---|
| | Eckernförde | Sonderburg | Laboe | Bay of Danzig | |
| 3 | 11.8 | 11.9 | 12.4 | 10.8 | —1.0 to —1.6 |
| 4 | 12.5 | 12.5 | 12.9 | 12.1 | —0.4 to —0.8 |
| 5 | 13.5 | 14 | | 12.7 | —0.8 to 1.3 |

Hessle's data as given in his work of 1927, "Sprat and sprat Fishery on the Baltic Coast of Sweden", appear to us dubious, as the growth rate of the Swedish sprat, according to Hessle's definitions, not only exceeds that of the West Baltic sprat but exceeds or equals that of the pre-eminent Norwegian sprat — with regard to two-year-olds.

**Conclusions.**

Summing up, we arrive at the following conclusions with regard to the composition of the sprat stock of the Bay of Danzig.

1) The sprat shoals consist of sexually mature sprats on their autumn-winter migration to the shores of the Bay.

2) The length of the fish varies from 6.5 to 15 cm., with the mode falling on fish of 12 cm.

3) In comparison with the season 1931—'32, the mode of the curve of length has shifted one centimetre higher, which would appear to indicate a better growth rate and, presumably, a certain thinning out of the stock owing to the great increase of trawl fishing.

4) The percentage of fat from December to June varies from 14.2 to 3.57. The maximum percentage occurred in December—January (14.2), with an average water temperature of 4.9°, the minimum in June (3.57), with a temperature of 14°.

5) Parallel to the gradual decrease in the content of fat in the body of the sprat is a gradual increase in the content of water, so that the changes in weight of the various groups are very slight.

6) Absence of distinct and considerable difference in weight throughout the whole fishing season makes it possible to apply Fulton's formula for comparing the qualities of sprats caught during the season.

7) The sprat stock in December 1935, consisted of 2½, 3½, 4½ and 5½ year old fish, with a majority of 4½ yearly (56 %) and 3½ yearly (34 %). The 2½ year old fish accounted for 4 % and are too small to be of use in the fish canning industry.

8) The growth rate of Middle Baltic sprat is less than that of the Western Baltic sprat.

9) The first distinct winter ring on the scale and otolith of the Middle Baltic sprat is acquired, as on the scale of the autumn herring, during the second winter of the sprat's life.